Proceedings for the
3rd Shaw-IAU Workshop
on Astronomy for Education

What Everybody Should Know about Astronomy Education

12 – 15 October, 2021

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The following is a summary of the 3rd Shaw-IAU workshop on Astronomy for Education held 12 – 15 October, 2021 as a virtual event. The workshop was organised by the IAU Office of Astronomy for Education. More details can be found on: `https://astro4edu.org/shaw-iau/3rd-shaw-iau-workshop/`.

The Office of Astronomy for Education (OAE) is hosted by the Haus der Astronomie on the campus of the Max Planck Institute for Astronomy in Heidelberg. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. The OAE is an office of the International Astronomical Union, with substantial funding from the Klaus Tschira Foundation and the Carl Zeiss Foundation. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

Foreword

3rd Shaw-IAU Workshop on Astronomy for Education

Teaching astronomy takes both solid knowledge of the subject itself as well as educational skills, such as knowing appropriate methods and techniques for teaching. To this, specific sub-fields of astronomy education add their own specialized skill sets: knowing how to operate remote telescopes, for instance, or the ins and outs of daytime observations. Last but not least, there are the skills needed in order to make our teaching fair, equitable, and inclusive.

In practice, most of us who are active in astronomy education have only been taught a subset of those skills in our academic training. Those who come from professional astronomy and have branched out into education and outreach typically have advanced training in astronomy, but not in the relevant areas of pedagogy. Most teachers, on the other hand, have pedagogical training as well as training in the subjects their teach, but often that does not include formal training in astronomy and astronomy education.

If this description includes you, and if in consequence you have ever felt motivated to expand your astronomy education skill set, then this workshop was, and is, meant for you. It is the third in a series organised as a collaborative venture between the Shaw Prize Foundation and the International Astronomical Union, and with 89 talks and 50 posters in a total of 18 sessions, it provides a fairly comprehensive "Astronomy Education 101".

For those who were unable to attend, or did not manage to attend all of the sessions they were interested in, we present these proceedings, and the associated talk videos from the workshop. While they lack the interactivity that the 580 workshop participants enjoyed as they posed their questions to the speakers, or interacted in the chat, we do believe that they are valuable in their own right — and we asked speakers to include in their write-ups helpful pointers to additional resources, so you have the opportunity to delve deeper. If you find these resources useful, and I hope they will be useful to many, please share them widely.

The workshop was made possible by funding from the Shaw Prize Foundation, for which we are very grateful. You can find the names of the individuals and institutions who organised the workshop on p. 11 — a big "Thank you!" to all of you!

For us at the International Astronomical Union's Office of Astronomy for Education (IAU OAE), this is just the start. Helping those who are active in astronomy education to grow their skills, and to become more professional in their activities, is one of our main objectives. Stay in touch if you want to make sure not to miss what is next — from additional events to more resources. On the web, you can find us at http://astro4edu.org, and on that page, you can also find your country's National Astronomy Education Coordinator Team. We are also on Twitter and on Facebook as @astro4edu.

Markus Pössel
Director, IAU Office of Astronomy for Education
Heidelberg, November 16, 2021

Contents

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In addition to the efforts from the OAE office in Heidelberg, Germany, the following OAE Centers and Node made key contributions to organizing this event:

OAE Center Italy

OAE Center Cyprus

OAE Node Nepal

The OAE Center India was not formally established at the time of this workshop but also made significant contributions.

astroEDU: Improving Educational Activities through Peer-review

Session organisers: Edward Gomez, Las Cumbres Observatory, California & Cardiff University, UK and Michael Fitzgerald, Las Cumbres Observatory, California & Deakin University, Australia

AstroEDU is a peer-review platform that aims to improve astronomy education activities. It was created in 2013[1]. It seeks to address the disparity between quality and quantity of astronomy education activities. A simple web search for an astronomy education activity will yield many results, yet the quality of, relevance and how current the results are is unclear. astroEDU uses peer-review to improve astronomy education activities, and then publishes the activities on its website. Each activity receives a review from a professional educator and professional scientist, to review the educational and scientific content in a constructive manner. The published activities are syndicated to online repositories, so the activities can achieve the maximum reach. As of 2021, astroEDU has 2 language editions (English and Italian) each with their own editor in chief and editorial board. The English language edition has published 84 activities and the Italian language edition has published 40 activities. Some of these activities are translated versions from one of the language editions.

The aim of this workshop was to encourage the community to create activities or amend existing activities to fit into the astroEDU activity template, and to give guidance about reviewing astroEDU activities.

Link for the talk by Edward Gomez:
https://youtu.be/nAOGZ6XbB8A

Link for the talk by Michael Fitzgerald:
https://youtu.be/vcKK0c6boAU

Figure 1: A word cloud of the qualities of a good review as suggested by the workshop audience.

Writing an article

The astroEDU activity template may have fields which are unfamiliar to you as a content creator. The aim with this template is not only to provide a guide to reproduce the activity but to provide extra information to the educator and meta-data for the astroEDU (to assist with searching and sorting). Some information you may not already include in your activity is:

Background information: This is important for non-specialists to be comfortable with the content and subject area. Try to make this a quick primer on the topic and include text, images and videos, as appropriate

Goals: These should be short and general. You should aim to have 2-3 for a short activity. Your audience should be able to achieve all your goals. An example of a goal is "Students should have an appreciation that gravity pulls objects towards Earth".

Learning objectives: These should be specific. You would like your audience to achieve the majority of these but there should be room to differentiate between abilities. An example of a learning objective would be "Students will demonstrate that objects of different mass fall to Earth at the same rate".

Evaluation: This is your opportunity to check that the students have learnt what you intend them to. You can do this in many different ways from asking your students questions as part of the activity, completing a survey at the end or something creative like drawing or making a poster. If your evaluation is part of your activity it is more likely the students will do it and you can learn from it.

Attachments: You can also attach extra documents that are useful for your activity. These may be in the form of printable documents the educator will need, videos for the students to watch or web resources.

Becoming a reviewer

During the workshop we asked the audience to describe, based on their experience and from the information given at the workshop, what makes a good review. The results can be seen in Figure 1.

The biggest suggestion is for reviews to be constructive. This is at the core of the astroEDU review process. astroEDU is aiming to improve the quality of astronomy education activities. We would rather not and have not, to date, rejected any activities. We would rather work with authors to make their activities as strong as possible, so they have the widest reach and widest impact possible.

astroEDU is currently seeking reviewers to assist with the peer-review process. We also encourage anyone who has written an astronomy education activity to submit it to astroEDU.

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1. Peer-review platform for astronomy education activities, P Russo, E Gomez, T Heenatigala, L Strubbe https://arxiv.org/abs/1501.07116

Astronomy across Disciplines

Session organiser: Stefano Sandrelli,
INAF - National Institute for Astrophysics, OAE
Center Italy, Italy

Session overview

The "Astronomy across disciplines" session was a ballet. It staged several scenes, going in different directions, all revolving around the same central point: how astronomy, and science in general, relates to other basic activities of the human mind.

This reflects the peculiarity of astronomy itself: every primitive culture, every society, whatever it is, wherever it is, developed a relationship of some kind with the day and night sky. Astronomy is "a necessary monster" (to quote the famous Argentinian writer Jorge Luis Borges), so we find it in every distinct place and time.

In fact, Astronomy is a *basic* human activity, like the art of sharing stories and information ("storytelling" is not a technique as it is - sadly - often regarded: it is a fundamental and pristine form of knowledge).

Consequently, in this session, we explored fruitful methods to create connections between astronomy and both art and other STEM disciplines: what are the best ways to promote a deep, creative and fruitful dialogue between astrophysicists and artists? How can we start from *Big Ideas in Astronomy* to draw a network of interactions among STEM disciplines? Can astronomy give a relevant contribution to promote critical thinking as a basic competence in a democratic and innovative society? What is the role of storytelling in this process?

A deep and honest dialogue and a mutual respect between professionals, cultures, point of views is the first step to get a good result. Dialogue and mutual respect, which also include creative and lively discussions, of course. With this starting point, it is all downhill from here.

Collaborations and Collisions in Science & Art

Speaker: Brendan Owens, Open Science Coordinator, Science Gallery at Trinity College Dublin, UK

What happens when science and art collide? The Science Gallery network explores this exciting frontier where scientists and artists collaborate to bring their combined effort to the public in a variety of head-turning exhibits and performances. This talk combines inspirational works from Science Gallery Dublin with the personal journey of the speaker; from physics undergraduate, to Public Engagement Manager at the Royal Observatory Greenwich to researcher at Science Gallery Dublin, Trinity College Dublin. The talk will include practical guidance on how to promote a healthy backdrop for innovation when combining disciplines for public consumption.

Talk link: `https://youtu.be/6PFS50Fbj00`

This talk focuses on practical guidance for astronomy communication broadly, as well as best practice specific to science and art collaborations. The speaker begins with a brief context setting piece to outline a number of observations from his science communication career so far, which feeds into the guidance. From there, the speaker addresses a number of stereotypes that any astronomer or scientist should be aware of when entering a public engagement setting. He gives a number of real-word examples to illustrate the gap between the public perception of astronomers and reality.

The talk also touches on the key understanding of the lived experience a person brings to the table in any given encounter. After this, the speaker then brings together some key tips and tricks that should prove useful to researchers when engaging audiences beyond their peer groups, especially if it is for the first time. The talk then moves on to explore the intersections of art and science practices to form a healthy foundation to explore collaborations between scientists and artists. This is followed by a list of key points to keep in mind when starting a collaborative project with artists. It includes advice on communication, awareness of practices and stereotypes, practical considerations, tone-setting and more.

The talk concludes with a number of examples of science and art collaborations in Science Gallery Dublin and the Royal Observatory Greenwich before finishing on some key takeaways to lead into the post-talk discussion.

Art-Science Collaborations at MIT: Case Studies

Speaker: Evan Ziporyn, MIT Center for Art, Science & Technology (CAST), USA

MIT established the Center for Art, Science & Technology in 2012, with the broad mission of creating new opportunities for art, science, and technology to thrive as interrelated, mutually informing modes of exploration, knowledge, and discovery. Partnering with laboratories, academic departments, faculty, researchers and students, CAST has since that time sponsored a wide variety of projects, including an ongoing Visiting Artist program that fosters robust collaborations between artists from a numerous disciplines with scientists, engineers, and technologists. What creates a successful collaboration? How is it defined and measured, what principles and models might be gleaned? This talk examines three such residencies: Agnieszka Kurant, Matthew Ritchie, and Tomas Saraceno.

Talk link: `https://youtu.be/TOM-cxkckec`

Since its inception in 2012, CAST has helped support numerous art-science collaborations. This talk is about a few of the more successful and robust collaborations that we have supported, to try to evince some commonalities between them, and to convey our basic operating principles and best practices.

Art-Science collaborations at MIT have a long history, as do arts innovations. In 1967 MIT was the first American university to establish a program in Artistic Research, the Center for Advanced

Dark Distortions by Thijs Biersteker on display as part of INVISIBLE exhibition in Science Gallery Dublin 2020.

Video Studies; 1985 brought the Media Lab, which has always involved significant participation of artists. These and other programs continue today, and demonstrate MIT's commitment to finding ways for art and science to mutually support and enhance one another, to co-exist. Collaboration implies a more embedded relationship, that is *direct* contact and *direct* cross-fertilization between the arts and the laboratory, between artists and researchers. Our center is keenly interested in this, and we consider our mandate to be somewhat 'free range' - to make connections between programs that otherwise might exist in isolation, allowing us to connect artists with particular labs, centers, and individuals in all disciplines; and to foster richer and more interactive forms of collaboration between them.

Our selection and development process – which continues to evolve – is based on these practices and principles: First, **proposals and buy-in from the MIT Community** – for us, a top-down approach does not work, for projects to be successful they need to have not just cooperation but rather the full engagement of a lab, a director, a program. To assure this we call for proposals from the community twice-yearly, in a way that begins very simply and briefly, a short letter from the applicant, followed by discussion to assess compatibility with our general mission and fiscal viability, o bolster the forms of engagement, if necessary to help find the right artist or partners, and try clarify goals and outcomes to the extent that these can be anticipated. We then ask for fuller proposals, which are then submitted to an internal Selection Committee of MIT faculty, researchers, and students. Once a project is funded, dialogue and facilitation continue, all the way through the project's completion. By following this practice we assure the project and the artist will be **embedded in ongoing research and teaching**. Through this process we also try to avoid selection bias. Rather than focusing on the end result, we look to the robustness of the collaboration itself - how mutually beneficial it potentially may be to the parties involved. We favor projects where **research and development** is on both sides of the aisle, for the lab and for the artist. We are mindful of **student engagement**, which can take different forms: some projects involve intensive ongoing work by graduate students, others are more about broader-based classroom experiences, others more public facing – lecture/demonstrations, installations, performances – because some kind of **public component** is essential. While every project has a stateable goal, we try to remain **flexible** and open to change, so that an environment is fostered that is conducive to unexpected outcomes.

In addition to accepting proposals, we also sponsor **Exploratory Visits** from potential artistic collaborators – relatively short visits with no fixed agendas, bringing an artist around to tour labs, have conversations, and see what might ensue.

This was the case with our Inaugural Visiting Artist, Tomas Saraceno, who first came to MIT in 2012, at the inception of CAST, for what started as an exploratory visit, but resulted in ongoing CAST-sponsored work at MIT in collaboration with three departments – Civil and Environmental Engineering; Earth, Atmospheric and Planetary Sciences; and Music & Theater Arts.

A few examples of what came out of that: first, spider webs. Tomas' interest here caught the attention of Markus Buehler, then head of Civil Engineering. Tomas was familiar with Markus' lab's research on spider web silk, and Tomas himself had developed 3D spider web scanning technology with TU Darmstadt. At MIT Tomas shared these scans with Markus' lab, and subsequently gave them their own tropical tent spider - a spider-in-residence, if you will. That spider built her own web, which the lab then scanned, using their own refinement of Tomas' technique. They then created a virtual 3D model of the web - and this led to a series of experiments, several research papers, and one dissertation. This impacted Tomas' own ongoing spider-related art, and sparked two other artistic collaborations, the Spider Salon Jam Sessions which Tomas organized for various venues, and the Arachnodrone/Spiders Canvas project that was generated here at MIT with myself, Isabelle Su, Christine Southworth, and Ian Hattwick. We see this as a successful residency, establishing an extremely symbiotic relationship between artists, engineers, and a spider.

Simultaneously, Tomas developed a relationship with MIT's Earth, Atmospheric & Planetary Sciences, in connection with his *Aerocene project*. Aerocene advocates fossil-free flight and has in fact conducted multiple test flights, some at MIT, but also including the world's first fully solar-powered human free flight, in Argentina. To assist in this work, a team of MIT atmospheric scientists developed software which Tomas named the "Float Predictor", an interactive website that uses atmospheric data to determine potential flight paths for the Aerocene, and which is now part of the project. This work has now been presented at numerous international venues, ranging from the Paris climate summit in 2015, to Saraceno's own large one-man exhibition at Palais de Tokyo in 2018. Researchers were able to channel at least some part of their work into an ongoing work of environmental art.

CAST's set some initial conditions, made meetings happen, facilitated dialogue – and the results were multidisciplinary and fluid: research both published and ongoing, tools for art and science, and new artwork both by Tomas himself and by others in dialogue with him. Outcomes both expected and unforeseen, and work that continues past the residency itself.

Next, the collaboration with highly distinguished visual Agnieszka Kurant. Her first project at MIT was a collaboration with a group of graduate students from a variety of disciplines, working on a 'signature hack' for MIT's annual Hacking Arts Festival, which we help to sponsor. The result was **Animal Internet**, involving live web-cams of polar bears and tigers convolved with algorithms calibrating crowd-sourced emotional responses from the Internet, resulting in what Kurant calls a 'collective Tamagotchi' - and only made possible by a collaboration that included work from multiple disciplines, and, of course, the right artist. Agneiska then began working with Boris Katz, a research scientist in CSAIL's InfoLab - CSAIL is the Computer Science and Artificial Intelligence Laboratory. The result was *Assembly Line*, a very different sort of crowd-sourced algorithmic sculpture, which involves an inversion of facial recognition technology. This then spurred a commission from MIT for Kurant to create a large piece of public art based on anonymous signatures for display on the facades of two new buildings at MIT in Kendall Square, again in collaboration with MIT computer scientists and students, and this work, The *End of Signature*, has been completed and installed. 3 significant works by an extremely interesting artist, all done - and indeed only possible in this particular iteration - by collaboration with MIT researchers.

In summary, what works is a combination of elements: an artist for whom preparatory research is part of their practice, and who is able to break their vision into concrete elements. Scientists who are willing to suspend disbelief, and who are able to release researchers and/or equipment from other projects. Under these conditions, a common ground can be established around experimentation, risk-taking, and problem solving. A successful collaboration generates rewarding outcomes in all collaborator's fields. Some threats to collaboration include conflicts around authorship and ownership, hierarchical divisions of labor in the laboratory, differing conceptions of problem solving, over reliance on preconceived outcomes, and external factors such as public interest or press skewing to one part of the collaboration to the exclusion of the other.

In our experience, what really works in a successful art-science collaboration is asymmetry, a willingness to embrace edge effects and a spirit of parallel play. A successful residency is an overture, not a conclusion, one that allows for duration and evolution and that embraces unexpected outcomes.

Life, The Universe and Everything: Science Fiction for Teaching Astronomy

Speaker: Julie Nekola Nováková, Laboratory of Evolutionary Biology, Department of Philosophy and History of Science, Faculty of Science, Charles University, Prague, Czech Republic and European Astrobiology Institute

Narrative helps people remember more facts and make connections between them, making it a useful tool for outreach and education in general. In science education, it is especially helpful to increase understanding of the process (scientific method) and interdisciplinarity. I will present examples and best practice for how scientists can use storytelling for science communication as well as how existing stories (be it science fiction literature, movies, drama or even opera) can be used to illustrate scientific concepts and elicit curiosity.

Talk link: https://youtu.be/xZMOTvLzK_0

'What has inspired you to pursue a career in science or technology?' A lot of scientists, engineers or entrepreneurs answer by citing science fiction as one of their early sources of inspiration. That is perhaps not surprising, given that this genre of storytelling is directly inspired by science and can showcase it to the audience. While most science fiction does not feature much realistic science and technology, using "technobabble" instead, it still often portrays science as an exciting venture worth pursuing (one example that comes to mind, which mostly uses fictitious "technobabble", but has constantly showed science in good light, is *Star Trek*).

Aside from inspiration, science fiction (SF) can be used more directly to teach scientific concepts. Narrative has been found to help learning motivation and knowledge acquisition, though it may depend on prior knowledge of the subject (Wolfe & Mienko 2007, Furman et al. 2007, Glaser et al. 2009). The interdisciplinary nature of the SF genre can reflect multiple scientific fields and help connect their findings for people (Vrasidas et al. 2015, Thévenon 2018, Jordan & Silva 2019). Last but not least, science fiction often features diverse characters and could be helpful in reaching underrepresented communities.

However, scientists using storytelling in outreach and education should remember that any story should primarily remain a story and not sacrifice narrative to include more scientific content – a better approach would be to start with a good story and *then* discuss the science in more detail.

Using this approach at the European Astrobiology Institute (EAI), we have produced a freely available e-book anthology *Strangest of All* (ed. Nováková 2020) of reprint SF stories with astrobiological themes, each accompanied by a nonfiction science essay and tips for use in classroom activities (high school/undergraduate level). Its success prompted us to create a more ambitious book of original stories and essays in both print and e-book. *Life Beyond Us*, containing 28 SF stories and essays, will be published by Laksa Media Publishing in cooperation with the EAI in fall 2022 around the time of the launch of the European Spage Agency's Mars rover *Rosalind Franklin*.

Numerous science fiction works, especially books, feature quite realistic science and can be used as starting points for outreach. To name only a few: *Contact* by Carl Sagan, *To Be Taught if Fortunate* by Becky Chambers, or *Project Hail Mary* by Andy Weir. Among movies and series, there are good examples too – book adaptations like *The Martian* or *The Expanse*, or original works such as *Europa Report* or *For All Mankind*. An extensive list of stories featuring various astronomical topics is kept by Andrew Fraknoi and the Astronomical Society of the Pacific (2015). Finally, one can even find drama and opera inspired by science and containing important scientific concepts, like Michael Frayn's drama *Copenhagen*, where the uncertainty principle is discussed, or Phillip Glass' opera *Einstein on the Beach*, alluding for instance on the topic of the theory of relativity. These and numerous other works present a good starting place to get science across to the general public.

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Interdisciplinary Links between the School Curriculum and the Big Ideas in Astronomy: A Case Study in Chile

Speaker: Lara Rodrigues, Pontificia Universidad Católica de Chile, Chile

Collaborators: Maximiliano Montenegro (Universidad de La Serena, Chile)

In this talk, we propose that the Big Ideas in Astronomy (Retr et al., 2019) can be used as a framework to relate different science topics in the curriculum to up-to-date astronomical ideas, thus allowing the development of astronomy literacy at school through interdisciplinary links. We present a case study in Chile, where we characterized the opportunities to learn astronomy within the science curriculum from grades 1 to 12 and identified all learning objectives connected with the Big Ideas. We show the development of two interdisciplinary classroom units in collaboration with Physics, Chemistry, Biology, Arts, and elementary science school teachers. Finally, we discuss the main achievements and challenges we faced in this project and some ideas for the future.

Talk link: https://youtu.be/kEM1GhuAPPgs

Astronomy has a great potential to awaken children's curiosity for science and improve their scientific literacy [1]. However, it has a small presence within the school curricula worldwide and is mainly descriptive and restricted to Earth-Moon-Sun topics [2]. In fact, all OECD member countries include astronomical topics in their school curriculum, but only 27% of the curricula explicitly mention some astronomy content in all grades, and these are mostly based on facts rather than concepts [3]. In Chile, home of the world's largest telescopes, astronomy is even more relevant as a vector for science education, and the last curricular reform increased the number of astronomical topics in the national science curriculum. However, this new curricular version has not been analyzed in detail.

The present talk proposes that the Big Ideas in Astronomy [4] can frame interdisciplinary links within the school curriculum to promote astronomy literacy, as it can relate other science topics in the curriculum to up-to-date astronomical ideas. This argument is based on the results from a case study of the opportunities to learn astronomy within the Chilean science curriculum and from developing two astronomy interdisciplinary units focusing on Big Ideas.

A curricular case study in Chile:

The study corpus includes the science sections of all Chilean curricular documents, from grades 1 to 12. The documents' learning objectives were split into smaller units (micro-objectives) to clearly identify the contents promoted in them, following a segmentation methodology [5]. Then, the micro-objectives (m-os) were classified according to their relation to astronomy (see table below). Finally, all astronomy-related m-os were classified in three dimensions: **astronomy subject** [3], **cognitive process** [6], and **Big Ideas in Astronomy** (BIA, [4]). This talk focuses only on the BIA classification, which used the eleven ideas from the original booklet definition of astronomy literacy.

Relation to astronomy	Criteria
Directly related (DR)	Micro-objectives that refer explicitly and exclusively to space phenomena or technology
Indirectly related (IR)	Micro-objectives that refer explicitly but not exclusively to space phenomena or technology or Micro-objectives that do not refer explicitly to space phenomena or technology but are connected to the Big Ideas in Astronomy (Retrê et al, 2019)
Not related (NR)	Micro-objectives that do not refer explicitly to space phenomena or technology and CANNOT be connected to the Big Ideas in Astronomy (Retrê et al, 2019)

The main results from this study were: first that only 8% of the m-os are directly related (DR) to astronomy, and these appear solely in grades 1, 3, 9, and 10. Alternatively, the m-os indirectly related (IR) to astronomy correspond to 14% of the science curriculum and are present in all grades. In this sense, less than 25% of the Chilean science curriculum can be related to astronomy.

Furthermore, regarding the classification in BIA (Figure 1), we can see that the DR m-os are present in 8 of the 11 BIAs, with a predominance of ideas 2 and 7. The IR m-os are distributed in 9 of the 11 BIAs, covering those absent in the DR ones and predominantly in ideas 10 and 5. Moreover, when looking at the whole graphic, we can see that the Chilean science curriculum could cover all BIAs, but with fewer opportunities for ideas 1, 3, 6, and 9.

In conclusion, the DR m-os occupy only a small portion of the Chilean science curriculum, representing a low percentage of all m-os, covering only a third of the school grades, with a small variety of astronomy topics, and predominantly with low cognition levels. On the other hand, the IR m-os appear in all grades and include more topics and higher cognitive processes. In this sense, it seems that the astronomy potential for science education is not well explored in the Chilean curriculum, but there are opportunities to address astronomy through interdisciplinary topics such as astrobiology, climate-change, and technology. Likewise, when looking at the classification in terms of the BIA, it seems that teaching astronomical topics through IR m-os is a way to improve astronomy literacy in school education. However, it is also challenging, because a teacher would need more profound knowledge in astronomy to notice these opportunities – so we should provide them with knowledge and resources.

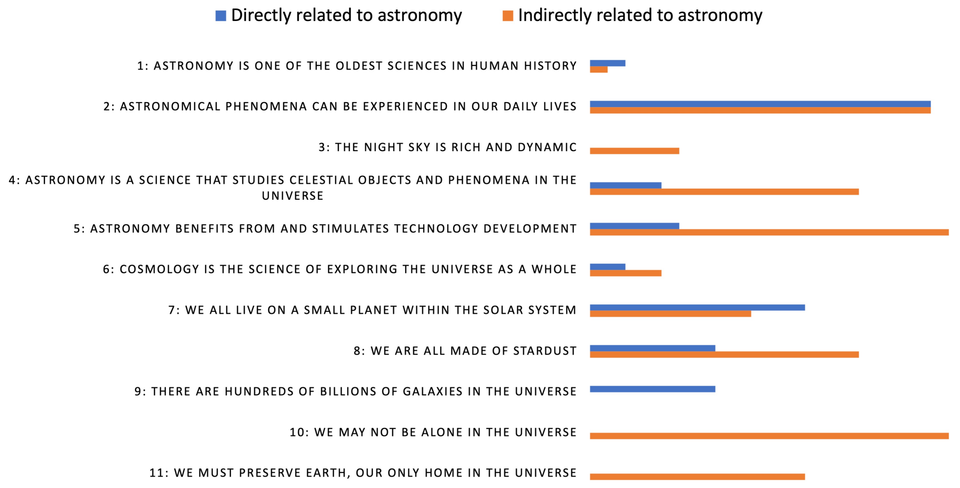

Figure 1: Micro-objectives (m-os) classification in terms of the Big Ideas in Astronomy (BIA).

Practical examples: interdisciplinary astronomy classroom units

The first unit focuses on BIA 10 (*we may not be alone in the universe*). It was developed in 2019 as a joint work with science education researchers and last year pre-service teachers in physics, chemistry and biology, and primary education science. We developed two parallel units (for both 3rd and 9th grades) with the same guiding question: *How can we know if there is life on a planet?* The units start with a motivation exercise with news about the TRAPPIST-1 system, proceed with an astro-game in 3rd grade and disciplinary tasks in 9th grade, and end with an activity to answer the initial question with evidence collected during the unit.

The second one focuses on Idea 7 (we are all made of stardust). It was developed in 2020 with three science education researchers and five secondary school in-service teachers in physics, biology, and arts. The guiding question was: *what is the meaning of "we are all stardust"?* The final unit is planned for nine classroom hours in 9th grade, including game development and an artistic installation at school.

Discussion and conclusions

The BIA can frame interdisciplinary links within the school curriculum to promote astronomy literacy, and a good practical application is the development of classroom units. However, it requires joint work with an interdisciplinary team (astronomers, education specialists, teachers, etc), so it is not a simple task. Thus, the astronomy education community must provide resources: we can make an international effort and develop local initiatives, detailing the interdisciplinary relations between the school curricula and the BIA, and create handbooks for teacher training and professional development programs, aiming to apply these results in the classroom.

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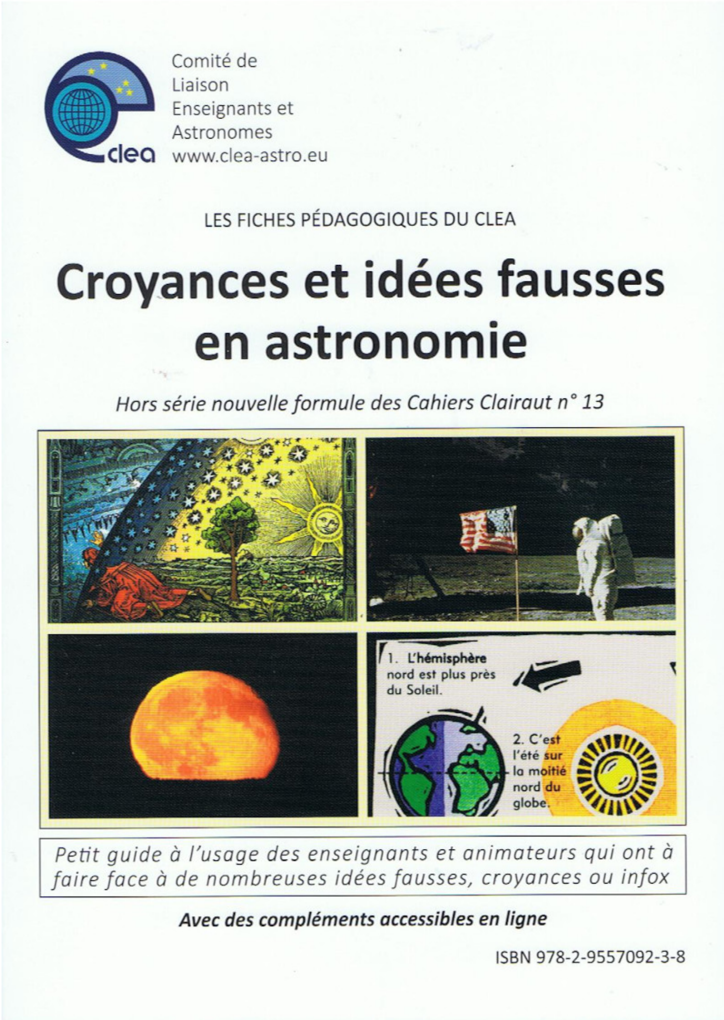
Teaching Critical Thinking Skills with Astronomy

Speaker: Frédéric Pitout, Institut de recherche en astrophysique et planétologie, Toulouse, France

Students, like all citizens, are inundated with all sort of news by the media and social networks. That news turns out sometimes to be completely false and it is not easy to make the difference between a trustworthy information and a fake news. In France, probably as in many other countries, raising students' - and teachers'! - awareness of critical thinking as become a priority. We shall discuss and illustrate with a few examples how astronomy can be advantageously used to train the three pillars of critical thinking: the scientific methods, including history of science and epistemology, media and information literacy, and the knowledge of the main cognitive biases.

Talk link: https://youtu.be/175U-qXQBhk

How long have we known the shape of the Earth and how was it determined? How can we fight against misconceptions about the phases of the Moon, the seasons, weightlessness etc.?



Cover of the book "Beliefs and misconceptions in astronomy" published by CLEA. It was written as a "small guidebook for teachers and educators who face numerous misconceptions, beliefs or fake news".

Are ancient beliefs about astrology or the Moon's influence on birth rate justified? What is the evidence that Americans went to the Moon? Search engines, social networks or media sometimes convey uncontrolled information, which combines knowledge and fake news, scientific information and beliefs or conspiracy theories. How to avoid these traps if our students do not have the reflex or the habit of analysing the sources of a presentation, the qualities of its author, the contradictory opinions? We therefore propose to explore three complementary ways for transmitting critical thinking skills: the scientific method to explain how astronomical (and more generally, scientific) knowledge is built, media and information education to transmit good practices, and finally raise students' awareness of cognitive biases. We think astronomy lends itself perfectly to this because it is far from sensible topics and rests on some robust knowledge.

Construction of scientific knowledge: the example of the shape of the Earth

To illustrate the construction of knowledge in astronomy, an interesting subject to explore is the shape of the Earth. Not only because some cast doubts on what we have known for centuries about the rotundity of our planet, but also and above all because it is a fine example that calls on various notions: astronomy, geometry, optics, etc. It is also a textbook case of reasoned debate (possibly ad absurdum) and illustration of the effects of rhetoric and cognitive biases that we will see later. The shape of the Earth is a typical example of knowledge that we all (or almost ...) have, but that we would generally have a hard time justifying, demonstrating. The curvature of the ocean on the horizon? Barely visible. We would rather point out that on the top of a lighthouse we can see further; that if the constellations visible in the sky depend on the latitude; that if the length of the shadows cast is, at a given moment, longer in Alexandria than in Syene (Eratosthenes' experiment), it is because the Earth is (nearly) a sphere. The interpretation of this experiment with a flat Earth also works, but it leads to a very small Sun-Earth distance that is in total contradiction to all that we know.

Media and information literacy

Identify the sources

We receive floods of information daily through multiple channels: TV, newspapers, magazines, websites, social networks, etc. It is not always easy to sort out what is trustworthy information and what is fake news. So we have to instil in our students some good practices. What is the source and is it reliable? Who is making the point? On behalf of whom or what is he talking about?

Reading images and graphs

In astronomy, photos of celestial objects, images recomposed from snapshots taken in wavelengths invisible to our eyes and computer-generated images are sometimes mixed up. Without more explanations and without the necessary scientific background, untrained students can easily be confused. It is then advisable to explain and insist on the way images are produced in astronomy. Also, we are showered with graphics to show such or such parameters changing over time; sometimes without the necessary captions, with truncated axes or a misleading colour code. Here too, it is essential to have some good practices when looking at and interpreting a graph.

Cognitive biases

This last theme, and not the least, is the result of decades of study and experience in psychology and social sciences. Cognitive biases are those little distortions in thinking that distract our brain from rationality. It is important that the students – as well as the teachers! – are aware of those. Regarding the things of heaven, a remarkable example is the role the Barnum effect plays in the belief in astrology. The Barnum effect (or the Forer effect, or the sink effect) explains that everyone will make even the vaguest description of any personality their own. Clearly, in a fuzzy description, we will find everything that applies to ourselves while obscuring the details that do not correspond. Psychologists speak of the subjective validation effect. Obviously, this effect is very popular with astrologists. However, studies and small experiments show unequivocally that astrology does not work (besides having no scientific basis). Another well-known bias, which wreaks havoc in the understanding of scientific facts and therefore in the acceptance of science, is the confirmation bias: each of us tends to give more credit to information that confirms what we already know (or think we know). This effect tends to form communities on forums and social networks where internet users sharing the same misconceptions maintain their own mistakes.

Being critical requires constant attention that our brains cannot handle. We can however be cautious and aware of our own limits in reasoning and being careful not to draw hasty conclusions from what we hear and see. We have presented some good reasons for teaching critical thinking skills through astronomy and outlined the method proposed by CLEA. This involves addressing three complementary areas: the construction of scientific knowledge, media education and awareness of cognitive biases. To go further, the reader can refer to the special issue number 13 of CLEA [1] and to the "Astronomy and critical thinking" dossier designed with the La main à la Pâte Foundation [2].

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- On-line resource "Astronomie et esprit critique": https://cqfd-lamap.org/astronomie-et-esprit-critique/

Integrating Earth & Space Science Education in our Schools

Presenter: William H. Waller, IAU/OAE/US-NAEC, Endicott College and The Galactic Inquirer, USA

Currently, the interdisciplinary science of Astronomy (or Space Science) is seriously under-taught in most primary and secondary schools. Instead, the core sciences of Physics, Chemistry, and Biology are typically emphasized. The Earth sciences, like the Space Sciences, are also poorly represented – despite their vital importance for our shared well-being. In this presentation, I argue in support of teaching the Earth & Space Sciences together, so that students can attain a more holistic understanding of their physical environment, how it came to be, and where it is headed. Such teaching (and teachers) should receive the same priority as in the teaching of Physics, Chemistry, and Biology as will be explained.

Poster link: https://youtu.be/B2xkVISh3YI

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Currently, the interdisciplinary science of Astronomy (or Space Science) is seriously under taught in most primary and secondary schools. Instead, the core sciences of Physics, Chemistry, and Biology are typically emphasized. The Earth sciences, like the Space Sciences, are also poorly represented – despite their vital importance in describing key processes within and among the rocky Earth, its ice caps, oceans and atmosphere that affect our shared well-being. In this presentation, I argue in support of teaching the Earth & Space Sciences together, so that students can attain a more holistic understanding of their physical environment, how it came to be, and where it is headed. Such teaching (and teachers) should receive the same priority as in the teaching of Physics, Chemistry, and Biology. My reasoning for bundling and advancing Earth & Space Science education has institutional, scientific, and cultural underpinnings. These will be discussed along with ideas for enhancing the interaction, cooperation, and coordination of Earth & Space Science educators worldwide (see https://drive.google.com/file/d/1iktmzxZYdwH2HsilFYp0FRzkcqt4fAM0/view?usp=sharing).

CALL TO ACTION:

To effectively bundle and advance Earth & Space Science education worldwide, our stakeholder institutions need to do a better job of interacting, cooperating, and coordinating. They include
1. Earth & space science organizations (e.g. NASA, ESA, IAU, AGU, EGU, AAS, etc.)
2. Science and education departments in colleges and Universities.
3. National associations of science educators (NSTA, NAGT, NESTA, NASE, ASP, etc.)
4. State boards of education (MA DESE, CA Dept. of Education, etc.)

I recommend that the IAU and AGU get the ball rolling by first establishing relations with the largest astronomical, geophysical, oceanographic, and meteorological associations. Once we have agreed upon tangible cooperative goals and strategies towards advancing Earth & Space Science Education worldwide, we could then reach out to engage the larger national science academies and associations along with national organizations of science teachers. These efforts at coordinating Earth & Space Science Education would help engender among subsequent generations a much greater awareness of and appreciation for our vital connections with the Earth, Solar System, Galaxy, and greater Cosmos.

Teaching the History and Philosophy of Astronomy

Presenter: Chris Impey, University of Arizona, USA

Astronomy is a subject with a rich and long history, and connections to the development of some of the most important ideas in physics. The philosophical implications of the subject are often neglected in introductory survey courses. A framework is presented for teaching the history and philosophy of astronomy in a way that engages students, lets them work in small groups, and encourages them to develop writing and reasoning skills. The class is enlivened by short videos and debates. This type of class appeals to a broad range of non-science college students.

Poster link: https://youtu.be/Zr__H2yh16g

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Pedagogy: The class is divided into thirteen weekly modules: Ancient Skies, Greek Science, Revolutions, Telescopes, Gravity, Evolution, Mapping, Relativity, Quantum Theory, Stars & Atoms, Galaxies, Big Bang, and Life in the Universe. The core content is 18 hours of video lectures, broken into shorter, 6-8 minute-topics, with associated slides. Half the class time is dedicated to debates and discussions, with students responding to weekly prompts in class, working in small groups, then doing individual homework each week on a discussion topic selected from a small list. Homework is presented in VoiceThread, a tool which allows for multimedia presentations, and which lets students easily comment on each other's work. A semester-long project allows for a deeper exploration of one of the topics of the class.

Learning Goals: This course is for non-science majors, and it does not assume any prior astronomy knowledge. Such students may not need astronomy after college but can benefit from an appreciation for our understanding of how the universe works. Learning goals are for them to be able to:

- Appreciate the role of logic and scientific method in advancing astronomy knowledge.
- Understand how different cultures conceived of space and time throughout history.
- Describe how dramatically our view of the universe has changed in the past century.
- Convey aspects of astronomy in a way that any non-science major would understand.
- Recognize the different roles of theory and observation in advancing our knowledge.
- Describe the relationship of astronomy to other fields of science, and also to religion.
- See how science strives for objectivity, but also operates as a human, cultural activity.
- Understand how philosophical thinking can work to advance astronomical knowledge.
- Demonstrate your comprehension of an astronomy topic in a multimedia presentation.

MOOC: A spin-off of this course is a massive open online class, or MOOC, developed for the Coursera platform. This lets the same material reach a very large audience of adult, lifelong learners. A MOOC typically free and not for college credit, but high-performing students can pay $100 for certificates of completion. The MOOC was launched in September, 2021.

Raising the Interest and Reaching out with Interdisciplinary Astronomy

Presenter: Maria Sundin, Department of Physics, University of Gothenburg, Sweden

Numerous people in varied ages and backgrounds are interested in astronomy, but not everybody. Having lectured in interdisciplinary courses in astronomy for more than 25 years, I would like to share some of the topics that have worked well to attract students that not normally would have applied for an astronomy course. These topics could be useful for all teachers since they (1) raise the interest for several students and (2) open for collaborations between subjects such as astronomy and e.g. history, art, music, philosophy, psychology, culture, navigation, sports as well as the natural sciences. The contribution will be built around 10 specific questions e.g. "Which phases of the moon are most common in art?", "Who will go to Mars?" and "What events are related to the Pleiades?".

Poster link: https://youtu.be/d7YjM7Z745A

Numerous people of all ages and with varied backgrounds are interested in astronomy, but not everybody. Having lectured in interdisciplinary courses in astronomy for more than 25 years, I would like to share some of the topics that have worked well to attract students that would not normally have applied for an astronomy course. These topics could be useful for teachers on all levels since they (1) raise the interest for several students and (2) open for collaborations between subjects such as astronomy and for example language, history, art, music, philosophy, psychology, culture, navigation, sports as well as the natural sciences. A vast number of interdisciplinary subjects and questions exist, something I would wish for everybody to be aware of when teaching astronomy. In this paper, I have chosen five specific themes as examples.

Astronomy and sports – Equestrians sports

How high can a horse jump on Mars? Can a horse breathe on Mars? Is it too cold for horses on Mars? These questions are related to equestrian sports. Most sports can function as an introduction to other planets or zero-gravity. Students can also be encouraged to invent new sports suitable for different gravities.

Astronomy and Art – The phases of the moon

Art showing the moon can initiate a discussion about the phases of the moon, calendars, the Apollo-project or perhaps a dialogue about shape and colour in an art class. Looking at many paintings of the moon, most likely you will find them depicting the moon in full phase or as a crescent. "The sheepfold in moonlight" by Jean-Francois Millet is one of the few paintings illustrating a gibbous moon.

Astronomy and Ethnology – The Pleiades
When will the weather turn cold? How far away is the dawn? Will the rainy season start soon? Countless people throughout history have looked to the Pleiades for the answer. The Pleiades is easy to identify. Explain why they can be used as a calendar or a celestial clock and talk about what they really are: newborn stars. As an alternative, you can initiate a combined project in ethnology or history and explore myths and usage of the Pleiades.

Astronomy, Technology and Architecture - Starships
Which is the best design of a starship? Is there gravity on a starship? How can a sustainable environment be created on a starship? Starships can be used to address questions in subjects such as physics, design, art, psychology, economics, law and literature. One advantage is that the theme of starships is easy to adapt to different age groups.

Astronomy and Navigation – The Vikings
How did the Vikings navigate? Can you use the sun to find your latitude? Why does the position of the sun in the sky vary? The Vikings sailed during the summer following almost the same latitude from Norway to Iceland, Greenland and North America. It is believed that they possibly used a gnomon casting a shadow on a small disc. Students can explore their creativity by learning to determine direction and latitude using the sun and a stick.

Resources:

- Maryboy, N., A guide to Navajo Astronomy, 2004 `https://www.raritanval.edu/sites/default/files/aa_PDF%20Files/6.x%20Community%20Resources/6.4.5_SD.10.NavajoSkies.pdf`

- Sølver, C., The Discovery of an Early Bearing-Dial The Journal of Navigation , Volume 6 , Issue 3 , July 1953 , pp. 294 – 296 `https://doi.org/10.1017/S0373463300027314`

- Instrument navigation in the Viking Age `https://www.vikingeskibsmuseet.dk/en/professions/education/knowledge-of-sailing/instrument-navigation-in-the-viking-age`

- Snedegar, K, Astronomy in Sub-Saharan Africa `https://doi.org/10.1007/978-1-4020-4425-0_8461`

- Sundin, M, et al., Two studies using space sports in education and outreach – Sailing on Titan and Equestrian Sports on Mars XXXth General Assembly of the International Astronomical Union, Vienna, August 20-31, 2018 `https://gup.ub.gu.se/file/207694`

Teacher Workshop for the Design of Astronomy Interdisciplinary School Lessons

Presenter: Maximiliano Montenegro, Instituto de Investigación Multidisciplinario en Ciencia y Tecnología, Universidad de La Serena, Chile

Collaborators: Lara Rodrigues (Pontificia Universidad Católica de Chile), Ruby Olivares, Carolina Molina (Liceo 1 Javiera Carrera), Gabriela Clares, Lorena Lastra, Gabriela Contreras, David Aparicio

In this poster, we present a workshop that aims to support the design of an interdisciplinary unit anchored in an astronomic topic, aligned to the national education standards to be applied at school time. By first identifying the students' needs and astronomy interests, the workshops support the teacher's design of a unit structured around a guiding question, with activities in every discipline that gather evidence to answer it, and a final assessment that integrates all the gathered evidence for answering the question. Its implementation in a Chilean public high school is also presented, where a group of five teachers of physics, biology, and art designed a unit to answer What does it means that we are stardust?". Finally, school conditions for a successful implementation are discussed."

Poster link: https://astro4edu.org/siw/p29

Although Astronomy is considered a gateway to other sciences, able to attract more minorities and women to science and engineering careers, its presence in National Science curricula across countries is relatively low, mainly concentrated in lower grades and promoted through descriptive contents (Salimpour et al., 2020). That is the case in Chile, where the problem has arisen (Marinkovic, 2016; Rodrigues, 2021;) and several solutions have been proposed. In our project, we created interdisciplinary lessons aligned to the curriculum as a solution to overcome these difficulties. Following Begg and Vaughan's (2011) definitions, in this work, we are focused on the readiest interdisciplinary work, namely multidisciplinary work, where a group of researchers works in parallel from their disciplinary-specific bases to address a common problem. However, interdisciplinarity is not easy to foster, and some conditions must be met (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005), like promoting bridges across disciplines, institutional support to those bridges, shared instruments, and locations and personnel policies that recognize interdisciplinarity.

In this poster, we present the structure of a Teacher Workshop designed to gather teachers, educators, and astronomers for collaborating to design astronomy-related and engaging multidisciplinary lessons aligned to the National Curriculum's learning objectives. The multidisciplinary unit was structured around a scientific question as a scientific practice (National Research Council; 2012) that rises from a current piece of news that should be answered by the students. Then, several activities were designed to gather evidence from every discipline involved. Finally, the last activity integrated all the gathered evidence and fully answered the scientific question. The independent activities across disciplines allowed teachers to manage their activities inside their school schedule and reduce the impact of the multidisciplinary lesson in the school organization. The final integrated activity was required to allow students to share a common view across disciplines of the worked-out problem. The teacher workshop spanned six weeks, starting with one week for defining the focusing question that would guide the unit. Then, it followed two weeks of activity selection, adaptation, or creation, one week for the design of the integrated assignment, and two more weeks for the final assembly of the unit. The final product was a multidisciplinary unit guided by the question "What does it mean that we are stardust?" with art, biology, and physics lessons aligned to their learning objectives. It was composed of eight lessons, five within one subject matter and three that included all three subject matters. The creation of this unit raised several challenges that are discussed in depth.

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Bringing the Sun to School

Presenter: Ana Cecilia Soja, Federal Institute of Mato Grosso do Sul, Brazil

This work is the result of a two-year project that aimed to introduce classic sky observation experiments into the regular high school curriculum. They connected areas such as Geography, Science, and Geometry and used low-cost material. Its main objective was to reconnect students with basic concepts of Astronomy and Science, showing that it is possible to locate yourself spatially, calculate the size of the Earth or even estimate the size of the Sun. Everything is achieved through just the observation of nature and basic geometric concepts. The students involved in it improved both their performance in the Math and Science classes and their vision about the scientific method.

Poster link: https://youtu.be/5WjVxm_msX8

This work is the result of a two-year project that aimed at introducing classic sky observation experiments into the regular high school curriculum. At the present time, where Science is both so important and the fake news is spreading, it is essential to take every opportunity to bring students closer to observational methodology and help them develop evidence-based thinking. So, the project was designed to bring students closer to Science topics through observation and show that the knowledge in Astronomy – and in Science itself! - is multidisciplinary.

The target was students from the early years of high school (15-16 years old), who had low achievement in Math and Science. They were invited to participate as volunteers after their classes, and we had 30 participants at the end. We did a lot of simple observational experiments using low cost material.

The first one was based on the classical experiment done by Erathostenes in the III century B.C in order to determine the Earth diameter. To perform it, you have to observe the smaller shadow of a bar in two different places of Earth at same time and compare their size. We did this experiment in partnership with a school in Argentina and our result was very close to the real value, which motivated the students in the beginning. In this experiment, we use just paper and a small wooden bar.

Another experiment that was very successful was the determination of the Sun's diameter. For this, we only need a piece of paper with a hole that projects the Sun's light on the ground. The students measure the diameter of the projected image and the distance between the paper and the sun image. As we know the distance between Earth and Sun, we can estimate the Sun diameter using basic Geometry. With several students taking data at the same time, it was still possible to discuss errors and arrive at a very precise value. The discussion about performing an experiment several times is also very important to show how Science works.

We also promoted sky observation and the construction of a solar clock. Many students had questions about basic topics, such as the Earth's movements and seasons that could be discussed during the activities.

These low-cost experiments helped students to understand the science as a whole process, while reconnecting them with the observation of natural phenomena. They used knowledge of different areas and made an approach between Astronomy and Geometry. To their surprise, they discovered that Astronomy and Maths are attached.

Our experience shows that doing this kind of activity can help students with low achievement both to improve academically in many subjects and change their vision about the scientific method.

Virtual Reality for Astronomy Education

Presenter: Jackie Bondell, ARC Centre of Excellence for Gravitational Wave Discovery, Swinburne University of Technology, Australia

Technologies such as Virtual Reality (VR) offer both promise and pitfalls when used in education settings. The visualisations can be awe-inspiring and provide users with a sense of scale of objects usually difficult to comprehend or visualise. However, VR can be logistically difficult to implement. In this case study, we will share how we are using VR-based programs for astronomy classroom lessons and highlight the choices we made in content and hardware to ensure the experience is engaging, relevant for participants, and cost-effective. Specifically, we will share Mission Gravity and Gravity Explorer, classroom programs in which students collaborate to create models of stellar evolution and gravitation by collecting and analysing data from virtual trips to stars and planets.

Poster link: https://youtu.be/5ufI0bv1Xk8

Virtual reality is a powerful tool for students to interact with and study features of the Universe. Technologies such as Virtual Reality (VR) offer both promise and pitfalls when used in education settings. The visualisations can be awe-inspiring and provide users with a sense of the scale of objects usually difficult to comprehend or visualise. However, VR can be logistically difficult to implement. In this case study, we will share how we are using VR-based programs for astronomy classroom lessons and highlight the choices we made in content and hardware to ensure the experience is engaging, relevant for participants, and cost-effective. Specifically, we will share Mission Gravity and Gravity Explorer, classroom programs in which students collaborate to create models of stellar evolution and gravitation by collecting and analysing data from virtual trips to stars and planets.

As a former secondary science teacher, the author approached the challenge of developing an education program to bring the science of topics related to stellar evolution, black holes, and gravity to the classroom in a manner that would be engaging to students and highlight current science and technology advancements while remaining true to the realities of the classroom. We decided to let the school's curriculum drive the development of our lessons and activity to ensure we were relevant for teachers. While keeping in mind bringing together the pedagogical skills of teachers, the science content skills of the researchers, and the technology that VR visualisation affords, we focused on five principles to design our education program.

1. The instructional Framework should be student-centered and allow the students to build their understanding of the topic by using their own observations within the virtual star lab of Mission Gravity or the virtual gravitation lab in Gravity Explorer.

2. We used the SAMR model (Puentedura 2014) to serve as a lens through which to evaluate technology and its meaningful use in the classroom, focusing on the relevant incorporation of technology for learning

3. The lesson plans used in the classroom are formatted on the 5-E Lesson Plan Model... Engage, Explore, Explain, Elaborate, Evaluate.

4. The virtual environments were developed in-house and periodically edited and improved based on feedback from teachers to allow the content to be driven by curriculum choices and best classroom practices

5. The VR equipment was chosen due to classroom, bandwidth, & cost constraints, while optimizing experience and allowing students to collaborate in their learning.

Additional Resources: Teaching Einsteinian Physics in Schools: https://www.routledge.com/Teaching-Einsteinian-Physics-in-Schools-An-Essential-Guide-for-Teachers/Kersting-Blair/p/book/9781760877712#, OzGrav Education and Outreach Resources: https://outreach.ozgrav.org/portal2/.

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Providing Education through Astronomy Clubs

Presenter: Myriam Alqassab, IAU-OAE NOC Bahrain, IDA Advocate and an observer for the AAVSO, Bahrain

Throughout my journey with astronomy, I found that many people are afraid to get involved in astronomy or share what they know with the public because they believe they are not educated enough, unqualified, or require a high education certificate in astronomy. In this poster, I describe how I started an astronomy club to educate myself and my community about astronomy, despite having no formal astronomy certificate back then. And I also discuss how this step opened bigger opportunities for myself and the members of Bahrain stargazers.

Poster link: `https://youtu.be/y8eaxKNKiOQ`

Proceeding with astronomy as a hobby or career might be hard at first for many, especially for those who live in a country where most people are uninterested in astronomy. Some may feel unqualified or not educated enough, or they may believe they require a high degree in astronomy to be involved in the field. Astronomy clubs play a big role in spreading awareness, knowledge and providing education by arranging stargazing sessions, seminars, webinars, workshops, and more. In the poster, I shared my journey about how I established the first Astronomy club in Bahrain, and how I succeeded in creating a passionate community of astronomy enthusiasts who would do anything to help me continue Astronomy outreach in our country.

Astronomy Education Without Borders

New approaches for international cooperation about Astronomy

Presenter: Exodus Chun-Long Sit, External Vice-President of Starrix, Hong Kong

This talk explores the reframing of future abilities and promotional strategies that would be crucial to Astronomy educators and advocates, in response to the changes in popular science promotion caused by the COVID-19 pandemic. Unlike the traditional observational events, through Transmedia Innovation, integrating science and arts could be an effective method to visualize the knowledge and values of Astronomy education, from reconstructing inspiring mindsets to building a shared-valued community without borders. It could also contribute effectively to interactive teaching and design thinking for solving real-life problems related to Astronomy.

Poster link: https://youtu.be/IRruDurL0Gg

Traditionally, observational events are organized by regional astronomical organizations and space museums, specifically amateur astronomers and enthusiasts. Global collaboration with experts' concerted efforts induces a synergy effect within innovative festivals, such as Global Astronomy Month (GAM), IAU 100 Global Celebrations, and International Dark Sky Week (IDSW). Taking advantage of social media channels and interactive communication tools, it would be beneficial to gather astronomy professionals and stakeholders from different disciplines, including senior mentors and youth advocates, and keep updating approaches for creating promotional materials and shared-value open resources.

Despite the anticipated consequences of the COVID-19 pandemic, the great passion for organizing festivals had not been affected by provincial and territorial restrictions on travel. This provides a space for thinking and redefining the methodology and strategies of astronomy education, in discussion with national coordinators from other places and continents through online conferences and seminars. Gathering with people around the globe instantly can be encouraging to explore potential partnerships with common goals and interests. This can become an invaluable experience to express ideas without the limitations of regions, time zones, languages, technologies, and resources. Festivals are not only for traditional celebration and heritage conservation, but can also share happiness and cultural values by encouraging cooperative learning and inspiring discussions, cultivating future abilities and common sustainability goals as change-makers.

Discussion summary

An issue clearly emerged in our discussion: whatever action one takes, specific care should be taken in relation to any "minorities". For example, the community called for art & science initiatives capable of engaging visually-impaired people too, with specially designed exhibits or pieces of art. There were also worries about possible conflicts of astronomy-related artistic projects, which imply interventions in the public space and may affect the interests and sensitivities of local populations.

This also applies to the use of storytelling, given its historical and local traditions, which vary from country to country. While its power as a teaching tool is widely recognized (for example Storylines are embedded in the Next Generation Science Standards in the US), care should always be taken to consider local or area authors too – even in Science Fiction's use for education. On the other hand, an added value of SF is the development of a clear awareness of different ethics and the acceptance of diversity.

Thanks to Big Ideas and to a process of concrete co-designing, teachers and educators can be engaged more deeply. They can help the community to effectively link astronomy to actual school curricula. The specific links depend on the school level and on the specific country. The links between Astronomy and all the other disciplines should make it possible for teachers to use *astronomy for education*, which is the vision of our community.

Astronomy education should not strengthen the divisions among different disciplines; rather, it should show that culture and knowledge are a whole - made up of different points of view, strategies, references and so on. And that different types of knowledge can co-exist without contrasts.

The social processes in the construction of science are of great importance. The use of astronomy in promoting critical thinking can gain from a proper interaction with the sociology of science (and with anthropology, pedagogy and so on).

Astronomy Education Research 101

Session organiser: Saeed Salimpour, Office of Astronomy for Education/Max Planck Institute for Astronomy, Germany and Deakin University, Australia

Session overview

Astronomy Education Research (AER) as a discipline-based researched field is rich, layered and multi-dimensional, drawing on a range of fields and subfields, which includes but is not limited to education, cognitive science, psychometrics, astronomy (and its cognate disciplines) for content knowledge, and various others.

The AER 101 session was aimed at providing an overview of some key aspects of AER, each of these can be unpacked and explored in much more depth than is possible in a single or multiple sessions. Given this aim, the session brought together a panel of experts with vast experience in conducting AER: Janelle Bailey (Temple University), unpacked Quantitative Methods in Astronomy Education Research; Julia Plummer (Penn State University), provided an overview of Qualitative Methods in Astronomy Education Research using projects to highlight the characteristics of qualitative research; Kathy Cabe Trundle (Utah State University), highlighted the complexities involved when conducting research with schools and teachers, and the three types of teachers based on their engagement (learners, vacationers, and prisoners); Erik Brogt (University of Canterbury), emphasised the importance of ethics when conducting research, and how as researchers we need to make this our top priority (cardinal principle); and finally Urban Eriksson (Lund University), editor of the Astronomy Education Journal, highlighted the avenues for publishing when it comes to AER.

Quantitative Research Methods in Astronomy Education Research

Speaker: Janelle M. Bailey, Temple University, Philadelphia, PA, USA

The use of quantitative research methods within astronomy education research is appropriate for answering questions about changes in or relationships between variables. Quantitative data comes in multiple types (categorical/nominal, ordinal, interval/scale, or ratio) and different analysis strategies are appropriate for each. Although assessing p-value for statistical significance is common, it should be used in conjunction with other indicators of statistical quality. Effect size is one of the most important indicators but should be put in context of prior work and theory that drives the research question. It is critical to ensure that there is strong alignment between your study's literature and theoretical framework, research questions, data collection, data analysis, and discussion.

Talk link: https://youtu.be/yBMDcWKBHO0

Quantitative research methods are very common within astronomy education research (AER). As such, it is useful to keep in mind a few basics before deciding to embark upon this approach. Many people with astronomy backgrounds will feel quite comfortable with quantitative methods because they may have used similar statistical analyses within astronomy research, and they are generally at ease with mathematics. Of course, being proficient in quantitative methods would likely require a great deal of learning and a large time investment – for example, multiple semester-long courses or their equivalent. We cannot come close to covering everything here, so instead I take the focus of hitting some highlights, important or common terms, and foundational considerations for anyone who might not already have experience with quantitative methods. Quantitative methods are typically used for three purposes: to measure differences between groups, to understand relationships between variables, or to test hypotheses.

In AER, the group differences question is very common – for example, you might want to compare grades for students in a course section using a new intervention with students in a section using a traditional instructional approach (or not using the intervention in question). Physics education research (PER) has been using quantitative methods to better understand the relationship between race/ethnicity and Graduate Record Examination (GRE) scores to determine whether or not the GRE is a good criterion for use in graduate admissions (spoiler alert: it is not!) Finally, you might want to test a hypothesis such as, 'higher spatial reasoning scores will yield higher final course grades'.

Once you have determined your purpose, you also need to think about the type of data you can collect. Quantitative data are those that are — or can be converted into — numeric format. There are four types of quantitative data. *Categorial* (sometimes called *nominal*) are data that are distinct types but that have no inherent order to them. A classic example of this is gender – although we could assign female to be 1, non-binary to be 2, and male to be 3, there is nothing about these classifications that indicate whether one is higher or more intense or better than the others as might be interpreted from the assigned numbers. *Ordinal* data are those that do have an inherent order but that there is not necessarily equal separation. Education level (e.g., K-8, high school, college, graduate school) does have an order to it (those examples are listed from lowest to highest level) but the number of years in each is not necessarily the same. Another common example of ordinal data is the Likert scale (e.g., 1 = strongly disagree to 5 = strongly agree), as there is no guarantee that one person's difference between 3 and 4 is the same as their difference between 4 and 5 or as another's differences. *Interval* or *scale* data are ordered numbers with equal separate; age, barring leap years, is a great example of this. Finally, *ratio* are interval data where 0 means there is no measure of that data. Time on task might be an example from education; temperature measured in Kelvin is a physical science example (note that temperature measured in Celsius or Fahrenheit is interval data). The types of statistical analyses you can perform vary depending upon what type of data you have — for example, a mean or median of categorial data is meaningless, but frequency or percentage of each category is appropriate.

A decision tree, such as that found in Figure 2.2 of Mertler and Vannatta (2002), can help you decide what type of analysis is appropriate based upon the number and types of variables (both dependent and independent) you have. Some of the common analyses you will see within AER include t-tests, different analyses of variance (ANOVA, ANCOVA, MANOVA, or MANCOVA), linear regression, factor analysis (exploratory or confirmatory), or structural equation modeling. T-tests, a special case of the ANOVA, are among the most commonly used. Most of these tests will provide some measure of *statistical significance*, often designated by *p*-value; .05 is most common in education research, though sometimes .1 is used, and smaller values are typically preferred. The *p*-value is a measure of how likely it is that the observed effect is real compared to a statistical model. That said, there are a number of reasons to not rely solely on *p*-value (see, e.g., Wasserstein & Lazar, 2016, and associated pieces). One way of better parameterizing your results is to include *effect size*, an estimate of the magnitude of difference (or of relationship) between variables (Ferguson, 2016). There are different effect size measures depending upon your research question, data, and analysis. Kraft (2020) provides a great discussion on interpreting effect sizes in a way that puts them into context for the type of research at hand. Effect size is particularly useful for comparing multiple studies because it allows for formally analyzing data that comes from studies with different number of participants, analysis types, etc., such as in a metaanalysis where a single omnibus effect size is the goal (a PER example is by Madsen et al., 2015) or a systematic review where the effect sizes are used to support clarity without the omnibus calculation (e.g., Lombardi et al., 2021, which includes AER and PER as well as other disciplines).

As you embark upon a quantitative research study (ok, really any kind of study), you want to make sure there is strong alignment between its different pieces. The background literature and theoretical framework should explore what has been done and lead into well-informed research questions. Those research questions should define the types of data and methods of collection. Quantitative analyses should be determined by the research questions and data types. And the results and discussion should connect the analyses back to the theory and prior literature to show how the study contributes to our understanding of the field. Ensuring such alignment is critical for robust research design and implementation. The American Psychological Association (APA), whose guidance is typically followed by education researchers, have provided 'journal article reporting standards' that will help you consider what to include and how to present common types of data (see https://doi.org/10.1037/amp0000389 for the quantitative JARS; there are qualitative and mixed methods JARS available as well). Finally, if you are not comfortable with quantitative research methods, collaborating with others is a great way to get going.

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Qualitative Research Methods in Astronomy Education Research

Speaker: Julia D. Plummer, The Pennsylvania State University, USA

Qualitative researchers are concerned with how the social world is interpreted, experienced, or understood. Qualitive research methods are useful when exploring or identifying unanticipated phenomena, generating new hypotheses, and gaining a better understanding of an educational context or problem. This presentation will introduce you to qualitative research methods and when they are appropriate to astronomy education research questions; why this methodological tradition can contribute to a deeper understanding of teaching and learning; and provide examples of how to use qualitative methods during studies of astronomy education.

Talk link: `https://youtu.be/73-Jb4RQVk4`

This talk provides a broad overview of qualitative research, focusing on when it is appropriate to use qualitative research and some elements of the design of a qualitative research study. Below I describe a few resources that will give additional depth if you are interested in pursuing qualitative research.

Books on qualitative research methods

Glesne & Peshkin (1992). Becoming Qualitative Researchers: An Introduction. Longman.

I cited this text in my talk as it provided a helpful table contrasting qualitative and quantitative research. The book helpfully clarifies how to think about the role of the researcher as an observer or participant or both, in your research.

Maxwell (1996). Qualitative Research Design: An Interactive Approach. Sage Publications.

I found this book to be especially helpful as I designed my talk. If you are interested in learning more about the design of qualitative research studies, this is a useful text as it clarifies the nature of each aspect of the qualitative research design with helpful examples.

Merriam (1998). Qualitative Research and Case Study Applications in Education. Jossey-Bass.

One useful type of qualitative research is case study, an "intensive, holistic description and analysis of a single unit or bounded system" (Merriam, 1998, p. 12). This approach is useful when you want to develop an in-depth understanding of a situation and the people involved.

Saldana (2016). The Coding Manual for Qualitative Researchers. Sage.

Once you have taken the plunge and started doing qualitative research, you will soon discover that you need to think about the systematic process of moving from raw data to findings. Often this is through a process of generating codes and categories. This is a detailed guide to the process of coding and all the nuances you might need to think about when working with qualitative data.

Strauss & Corbin (1998). Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. Sage.

Another useful type of qualitative research is grounded theory. Grounded theory is "theory that was derived from data, systematically gathered and analyzed through the research process… A researcher does not begin a project with a preconceived theory in mind" (Strauss & Corbin, 1998, p. 12). This is one of the strengths of qualitative research – the ability to develop theory from data.

Learners, Vacationers, and Prisoners: Conducting Astronomy Education Research in PreK-12 Settings

Speaker: Kathy Cabe Trundle, Utah State University, USA

To improve science teaching and learning for all children, we must first understand effective strategies teachers use and the challenges they face in PreK-12 classrooms. Just as many biologist and geologist conduct field studies out in nature, educational researchers' field work often takes place in PreK-12 settings. This session focuses on astronomy education research with teachers and students and provides insights into successfully conducting research in schools.

Talk link: https://youtu.be/Uh_-BXNGFLM

Why?: Conducting research in school settings allows researchers to understand effective strategies teachers use and the challenges they face in PreK-12 classrooms. Just as many biologist and geologist conduct field studies out in nature, educational researchers' fieldwork often takes place in PreK-12 schools and classrooms. Partnerships and collaborations with schools and teachers allow us to work together to improve astronomy teaching and learning for all children. Schools, universities, and researchers share common missions. First, we work to expand the knowledge base of our fields, including what we know about effective strategies for teaching astronomy. Second, we strive to educate future generations while we instill and facilitate our students' interests in and fascination with the wonders and mysteries of the universe.

In order to maximize our influence on astronomy education in PreK-12 classrooms, we must communicate our research to broad audiences, including teachers. One such option is to publish our work in practitioner journals like *Science and Children*, *Science Scope*, and *The Science Teacher*. Our research team often works with teachers as co-authors on these articles. The inclusion of the teachers' perspectives provides authenticity to the manuscripts, and conducting research in schools facilitates these co-authoring opportunities to contribute the knowledge base.

How?: The key to conducting research in school settings resides in relationships – with school districts, science leaders, principals, and most importantly teachers. All relationships with school personnel should be founded on mutual trust and respect. As academicians, others may perceive us as disconnected and insulated from "real-world" realities and concerns. School personal may see us as aloof "ivory tower" dwellers. Working with teachers and students in PreK-12 classrooms can help bridge the ivory tower gap between universities and schools while increasing the relevancy of our work. Establishing close work relationships with teachers is critical for successful collaborations. A place to initiate a relationship built on trust comes from inclusion of a teacher partner as a member of the research team. Over the years my research teams have always included an educational researcher (me), a scientist (astronomer, geologist, physicist), and a teacher or teachers. When possible, and especially when working with groups of teachers, we also include a teacher peer mentor who has experience with the content and/or prior work experience with our team. The inclusion of teachers as research team members grounds our work in the realities of the classroom. The teacher serves as a integral team member in every step of the research from the design to implementation (instructional intervention) to data gathering and analysis to writing and publication. In fact, we have published numerous practitioner and research articles with classroom teachers as co-authors.

Where?: Our team experienced the most success in recruiting teachers as research partners by connecting through existing relationships. For example, we identify teachers who are interested in educational research via teacher professional development workshops and institutes that we provide. We also reach out to former students from our classes who are currently classroom teachers. Since these contexts allow for longer-term interactions and the establishment of trusting relationships, the teachers know us personally. And we have information to help us identify teachers who might be interested in the projects and who will likely be good contributing team members. While we have had the greatest success recruiting through existing relationships, in some cases we have contacted district science leaders and principals who recommend teachers who might be interested in the project.

Who?: In working with inservice and preservice teachers over the years, we have enjoyed collaborating with many science enthusiasts who are avid learners and great research collaborators. These teachers usually self-select to participate in the workshop, institute, learning opportunity, collaboration, and/or research team. The **learners** engage with the tasks and content, interact in positive ways with team members, contribute to discussions, and ask questions. In addition to learners, we also have worked with two other types of teachers that we characterize as vacationers and prisoners. We have the utmost respect and admiration for teachers and their commitments to and sacrifices for their students. By describing these characterizations, we do not intend to denigrate teachers, and the characterization is in no way a reflection of their effectiveness as a classroom teacher. Rather, these next two types of teachers usually emerge when an administrator selects and/or directs a teacher to participate in a project. In other words, the teacher's participation is not voluntary.

The **vacationer** teacher may self-select or be selected or directed by an administrator to participate. These teachers disengage for all or a portion of the experiences. The motivation for these teachers to show up for the experience can stem from an administrator directive, a desired break or vacation from the classroom, and/or the free materials offered with the experience – the souvenirs.

The final type of teacher is the **prisoner**. An administrator directs, shames (tries to fix a teacher who does not see herself as broken), or coerces the prisoners to attend the experience. These teachers disengage throughout the experiences, and they can be resentful about being forced or coerced to attend. Prisoners may openly complain about or even disrupt the experience. Thankfully, most of the teachers with whom we have worked over the years are definitely learners, with very few vacationers or prisoners in the mix. We have found our work with teachers whose motivations originate from sources other than learning or the research itself to be unproductive. Of course, we work to engage the vacationers and prisoners and provide opportunities and support so that they may shift toward being learners in the experiences.

I offer these characterizations so that you may be aware of the issue of why teachers show up for workshops, institutes, or research opportunities. Their varying sources of motivation may influence the nature of your relationship with them and affect the success of your research project. The key to successful research projects in PreK-12 schools resides in your relationships with teachers. Look for the learners and cultivate positive relationships built on mutual trust.

Human Ethics in Astronomy Education Research

Speaker: Erik Brogt, University of Canterbury, Christchurch, New Zealand

In most jurisdictions, research that involves human participants or data obtained from human participants is bound by ethical and legal requirements, and most scholarly journals require a statement confirming that projects have obtained the necessary approvals. In this session, we will explore some of the common ethical and legal requirements on astronomy education research, such as voluntary informed consent, power dynamics, data confidentiality, and the ethical use of secondary data sources. We will pay particular attention to potential ethical pitfalls when researching your own students, whether they are legal minors or not, and ways to avoid those pitfalls through good and ethical research design.

Talk link: https://youtu.be/_vMGTUItZvU

Astronomy education research means doing research with humans, on how they teach and learn astronomy. This means that as researchers, we are bound by the legislation, regulations, and human ethics protocols to do our research. These were set up in the wake of a number of biomedical and socio-behavioural experiments that resulted in physical and/or psychological harm to participants. For many beginning astronomy education researchers, especially those coming from astronomy or physics, human ethics processes are a new concept. But in a sense, the ethics committee serves a similar function to a Time Allocation Committee for a telescope. Just like you cannot just go to a professional telescope and expect to be able to take data without having gone through an approval process, you cannot go out and collect data from human participants without some form of external scrutiny. In addition, most education journals require a statement of having obtained the appropriate ethics approval as part of the submission process. At its best, the ethics process is an opportunity to engage in constructive dialogue with knowledgeable colleagues on how to best design and do your research in a way that helps you answer your research questions while minimising impact on your participants (who might very well be your students to whom you also have a duty of care). An ethics application typically covers a number of distinct elements: Recruitment; Methods; Informed Consent; Privacy and Confidentiality; Data Storage, Access, Security, and Future use. These cover the typical questions that would come up in your mind if someone were to ask you to participate in a study. In astronomy education research, as in most discipline-based education research fields, a lot of research is done by researchers with students who they also teach. This provides unique ethical challenges related to these five points that need to be carefully thought through to ensure that the research is done in an ethically appropriate way. It is the author's firm conviction that when we do research with students who we teach, our duties as a teacher take precedence over our research study, and research design and methods should not diminish the student experience.

Recruitment and informed consent Potential participants should be able to decline to participate without fear of retribution or penalty. As teachers, we hold a position of power over our students. As such, when we ask students to join our research project, they may feel coerced to participate, even if they do not really want to. In some cases, in an attempt to increase participation rates, researchers link participation to a percentage of the course grade or extra credit. At that point, students will be penalised for not participating, which definitely would be considered coercive.
A particular point is the use of data that was gathered for another purpose, for your research. It is worth keeping in mind that while you may have access to data in your capacity as a teaching (e.g. student grades, demographic data, GPA), you cannot use that for research purposes without ethics approval (which will most likely insist on consent from the students).

Methods As astronomers and physicists, we are comfortable with experimental designs (randomised trial, randomised control) and quantitative methods such as surveys and statistics. However, these designs and methods are not necessarily the right tools to answer the research question at hand. Qualitative methods provide additional unique insights that should not be overlooked or dismissed because we are not as familiar with them. One is not necessarily better than the other, they just are able to provide different data sets to paint a fuller picture. It is in a way comparable to photometry and spectroscopy. Both are valid tools for particular sets of research questions, one is not better than the other, and they each have their place.

An ethics committee typically has jurisdiction over methods, and they can require you to make changes or justify your methods if it is not clear how your chosen methods will help you answer the research questions. Gathering data that does not (seem to) serve a purpose goes against the concept of minimising impact, as you are in essence wasting participants' time.

Privacy and confidentiality, and data security The right to privacy is absolute and participants have a right to know how the data will be used, published and what the long-term plans of the data are (e.g. longitudinal studies, merging with other data from other institutions etc.). An additional ethical concern is when you know who of your students has participated in the study, and the students know this as well. This might lead to pressure to participate, or data bias in the sense that students say what you want to hear, rather than what they think. It is critical that data is anonymised as soon as possible, preferably by someone else than the teacher / researcher, that the teacher / researcher does not look at the data until teaching is over and final grades have been submitted, and that the students are made aware of this.

Where to go for help and support?

- Your human ethics committee or board if your institution has one
- Colleagues in Education and the Social Sciences
- Educational developers in a Teaching Centre or similar if your institution has one

Further reading

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Publishing in Astronomy Education Research

Speaker: Urban Eriksson, Swedish National Resource Centre for Physics Education, Lund University, Sweden

Last year the new international Astronomy Education Journal (AEJ) was launched and the first issue will be published soon. In this talk I will present the journal, its different sections. I will further present how to write manuscripts for the journal's different sections and how the manuscripts are being reviewed and/or curated. The journal is found online here: `www.astroedjournal.org`.

Talk link: `https://youtu.be/TgEQDZ0_4Yk`

Publishing astronomy education research (AER) and astronomy education (AE) material can be challenging when it comes to considering what journal to submit the manuscripts to. There are several international journals that do publish such articles but only very few that focus on AER and AE. Here we find, for example, RELEA and JAESE, but none that publish both AER articles and other AE material.

Further, when writing a manuscript for publishing one needs to follow many rigorous traditions when it comes to structure. Usually, journals provide templates, and these must be followed to be able to get a manuscript considered by the editors. Start by reading the guidelines for the journal you may consider for you manuscript and follow them when writing! When publishing AER manuscripts these rules are rather strict but when publishing other AE material, you are freer to do as you (and the editor) want. However, always strive to write short and concise and, if possible, cite relevant work by others. These manuscripts do not usually get reviewed by referees, but are curated by editor(s), sometimes after discussion amongst the editorial board members.

AER as a discipline-based research field draws on traditions from education and astronomy, and so manuscripts need to consider the theoretical and methodological frameworks that underpin each of the disciplines. This can often be challenging given that education research methods include both qualitative and quantitative approaches and philosophical underpinnings that are foreign to astronomy research. Therefore, it is important when publishing in AER to collaborate with those who are familiar with the approaches in either or both fields. At times it may be necessary to seek the experience of collaborators beyond those fields, for example, psychology, policy and governance.

At the inaugural IAU Astronomy Education Conference (AstroEdu [1]), we thus announced the new *Astronomy Education Journal* (AEJ). The journal is officially open and is accepting submissions of manuscripts – www.astroedjournal.org – and the first issue will be published shortly. This online journal aims to be a key global publication platform for both researchers and practitioners, in the field of Astronomy Education, Research, and Methods.

AEJ aims to meet the needs of the astronomy education community by providing a location for all manner of practical, newsworthy and scholarly publications involving developments in the field. In a sense, the journal tries to capture the original spirit whilst taking on board the important lessons from the, now out-of-print, Astronomy Education Review. By focusing on building community collaboration, disseminating important news and opinions, while also maintaining a section on more formal, technical, Astronomy Education Research (AER). This research section intends to compliment the current scholarly discipline-based work undertaken by Latin-American Journal of Astronomy Education (RELEA), the Journal of Astronomy & Earth Sciences Education (JAESE) and, recently, the acceptance of AER articles into Physical Review Physics Education Research (PRPER).

Inspired by our sibling, IAU Commission C2: Communicating Astronomy with the Public journal, the *CAP journal*, we will accept various types of articles. AEJ will draw on journals such as the *CAP Journal*, *Nature*, *and Science*, to incorporate both peer-reviewed and non-peer reviewed articles. There will be a peer-reviewed section of research articles that will be incorporated into AEJ's scholarly indices. These research articles will be formally peer-reviewed as traditional scientific journal manuscripts and, as such, need to be of a sufficient scholarly standard as recommended by, for example, Scopus. In addition, there is also scope for published invited reviews written by specialists of the area of AER.

There will also be a less formal, non-peer-reviewed, but edited and curated section that contains other relevant material, such as, news, announcements, interviews, opinions, resources, correspondences, best-practices, classroom and astronomical activities, to help circulate information among the community.

We welcome everyone to submit manuscripts to AEJ by visiting: www.astroedjournal.org

[1] Held in Garching, Germany, 16-18 September 2019, https://iau-dc-c1.org/astroedu-conference/

Poster contributions

Importance and Particularities of Astronomy Education: What the Research Says

Presenter: Rodolfo Langhi, São Paulo State University (Unesp), School of Sciences, Astronomy Observatory, Brazil

This presentation shows that research results in the field of Astronomy Education point to justify the importance of its teaching and some of its particularities that differentiate it from other sciences. What are the aspects that differentiate Astronomy from other sciences regarding its popularization and teaching? Why is it important to teach Astronomy? What Astronomy is present in the Brazilian government curriculum? The answers are presented using the results of research in the field of Astronomy Education through a bibliographical survey.

Poster link: https://astro4edu.org/siw/p32

This paper shows that research results in the field of Astronomy Education point to justify the importance of its teaching and some of its particularities that differentiate it from other sciences. What are the aspects that differentiate Astronomy from other sciences regarding its popularization and teaching? Why is it important to teach Astronomy? The answers are presented using the results of research in the field of Astronomy Education through a bibliographical survey. This study is a qualitative research in Education and the method of analysis of data is the Content Analysys (Bardin) with bibliographical survey. The phases of this study are: Pre-analysis, Material exploration, Treatment of obtained results and interpretation. The corpus of analysis are the academic bibliographical production in Brazil ("voice" of researchers): journals of "Banco da CAPES", "Teaching" Area (from 2004 to 2017); thesis and dissertations about Astronomy Education (from 1973 to 2018); proceedings of Brazilian scientific congresses (from 2004 to 2017).

The results of this research answer the question: It is important to teach Astronomy because: It Awakens curiosity and motivation in students and people in general, because the Astronomy is "popularizable", favoring scientific culture; Teaching Astronomy can demystify some common-sense ideas or misconceptions; Frees the student from certain fears and ignorance; Illustrates and contributes to a vision of scientific knowledge as a process of historical and philosophical construction; It represents a clear example that science and technology are not far from our society; It is highly interdisciplinary, because Astronomy connect with other disciplines; Its physical objects of study are beyond the eyes of students, we cannot "touch" most astronomical materials to be properly analyzed; It is basically a visual science - the teacher needs to make use of pictures, photos, videos, models and other specific teaching resources; It enhances teaching work focused on the practice of experiments and models 3D, because three-dimensional astronomical phenomena is not always understandable in teaching with a two-dimensional figure; It involves systematic observation of the sky with the naked eye and with telescopes; Your laboratory is natural and free, with sky available to everyone; Many of the phenomena observed in the universe have never been, and are not usually found or reproduced on Earth; Its study challenges the ability of imagination and understanding; Allows the existence of an amateur area - amateur astronomers collaborate with observational data and studies; It enhances citizenship and interpersonal and social relationships (amateur or scholar clubs and associations); It favors the construction of specific non-formal teaching spaces (observatory, planetarium); Learning Astronomy we can note the errors in the sensationalist media news and conceptual errors in textbooks; Learning Astronomy, the teacher not needs to feel fear of this content, neither run away from teaching it; It leads the human to mental restructurings that surpass intellectualism and simple knowledge; Studying the universe provides the development of unique aspects of the human mind: fascination, admiration, curiosity, contemplation and motivation; Only understanding the dimension of universe, we can develop awareness of the urgent need to take care of our planet (the only possible home to live for now).

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Astronomy Alternative Conceptions in Pre-service Science Teachers

Presenter: Leonor Huerta-Cancino, Universidad de Santiago de Chile, Chile

Student's alternative conceptions are persistent, and teachers should be aware, to address them.But teacher´s alternative conceptions can influence their students to elaborate alternative conceptions too. To prevent this from happening, it is necessary for teachers to be able to differentiate between scientific concepts and the most common alternative conceptions on the topics they teach in school.In this sense, an important step is to identify pre-service teacher´s alternative conceptions, to then develop didactic designs that facilitate the learning of scientific concepts, with the aim of pre-service teachers do not use alternative conceptions at the time they teach astronomy or science in schools.

Poster link: `https://youtu.be/OsEbcI1erQI`

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In this sense, an important step is to identify pre-service teacher´s alternative conceptions, to then develop didactic designs that facilitate the learning of scientific concepts, with the aim of pre-service teachers do not use alternative conceptions at the time they teach astronomy or science in schools.

My research was designed to identify and to analyze most common alternative conceptions (CAM), of future Physics teachers, for three cohorts (2014, 2015 and 2016). Categories of analysis were defined allowing to select a set of CAM for which it was determined the need to develop specific teaching sequences to facilitate future Physics teachers learning the current scientific knowledge on those contents. To identify CAM, it was used a modified version of the standardized test Astronomy Diagnostic Test v2.0. Results show a limited set of CAM, similar to the three groups, on the following topics: movements in the celestial sphere, sizes and distances at scale, moon phases, eclipses and seasons, and star's properties.

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Statement of Astronomy Education in Chile

Presenter: Angie Barr Domínguez, Universidad Autónoma de Chile,
NAEC Chile team, Chile

Collaborators: Carla Hernández (Universidad de Santiago de Chile), Daphnea Iturra (Universidad de la Santísima Concepción), Maritza Arias (Colegio Leonardo da Vinci Vicuña), and Hugo Caerols (Universidad Adolfo Ibáñez).

The exceptional conditions of the Chilean sky for astronomy have allowed it to be an undisputed leader concentrating 70% of world capacities. However, Astronomical Education in Chile is not a developed area. Currently, there is no teacher training in astronomy. In the primary education, the astronomy occupies only 6.25% of the topics in the Natural Sciences. After that, astronomy is lost until high school, when students are 15 years and older. For this reason, NAEC Chile team carried out the I National Conference of Astronomical Education, which arises from the latent need to strengthen the teaching and learning of astronomy in our country. As a result, it was possible to identify new topics of interest to teachers, needs for their training and to strengthen the study program at school.

Poster link: https://astro4edu.org/siw/p34

The exceptional conditions of the Chilean sky for astronomy have allowed it to be an undisputed leader concentrating 70% of world capacities(1). However, Astronomical Education in Chile is not a developed area. In primary education, astronomy occupies only 6.25% of the topics in the Natural Sciences area. The aim is to develop a state of art of astronomical education in Chile, for this reason meetings(2) and focus groups were held with science teachers of primary, secondary education and all people interested in astronomical education in Chile.

This research is explorative, using data collection with qualitative analysis techniques. The data collection was carried out through surveys and virtual meetings with teachers from different regions throughout Chile. In total, 256 people interested in astronomical education in Chile participated, of which 28% correspond to primary education, 41% correspond to secondary education, 11% correspond to preservice teacher, among others. The participants came from different areas of the country.

We identify some weaknesses in the teacher training about astronomy education. The activities and resources most used in class are videos and models, and the least frequent are observations of the sky with their students in class. In the scholar programs, there is a discontinuity of astronomy from the third to the ninth year of schooling (9 years old to 15 years old). From this there is consensus in the interest to expand the astronomy contents incorporated in the curriculum, and connect astronomy with other areas of knowledge, such as mathematics, history, arts, etc., as a multidisciplinary science. With this review it was possible to characterize the experience of teachers on Astronomy Education in Chile and identify the challenges faced by teachers to teach astronomy at different educational levels. Lines of action for future investigations are proposed according to the findings like:

1. Establish a link between program experts and work with the local educational community to modify the curricula.

2. Organize teacher training events and developing educational material adapted to the needs of our country.

3. How to promote astronomy in an integral way in the school program.

References: Reaching for the Stars, Alcanzando las Estrellas: Hallazgos de las Cumbres Chileno-Estadounidenses de Educación y Difusión de la Astronomía Santiago de Chile, noviembre de 2016, https://sites.google.com/view/naec-chile

Justifications for Teaching Astronomy in Basic Education: A Look at Research Carried out in Brazil

Presenter: Antônio Carlos da Silva, University of São Paulo, Brazil

Collaborators: Rubens Parker Mamani Huaman (Cristina Leite), Raquel Gomes dos Santos (Inter-unit Post-Graduation in Science Teaching, University of São Paulo)

It presents a survey of the last ten years, of the importance and justifications attributed to the Teaching of Astronomy by Brazilian researchers in the area, in their investigations. Of 220 works found in journals related to this field of knowledge, arguments were identified in 67 of them. To verify the nature of these justifications, categories established by Soler (2012) were used: the awakening of feelings that astronomical themes can arouse in different audiences; the socio-historical-cultural importance attributed by humanity to Astronomy; the possibility that this Science can broaden the worldview and raise awareness on issues such as environmental preservation and citizenship; and the ability that Astronomy has to interrelate with other areas of knowledge (interdisciplinarity).

Poster link: https://astro4edu.org/siw/p35

Many researchers in Astronomy Teaching affirm in their investigations the need to promote the dissemination of teaching in this discipline through the stages of Basic Education (LANGHI; NARDI, 2014). Thus, we seek to answer "how do Brazilian researchers in the field of astronomy education justify the importance of this teaching in Basic Education?". This work, of bibliographical review, inserted in the perspective of qualitative research, analyzes the main periodicals in the area in Brazil published between 2010 and 2020 in order to map the main justifications for the teaching of astronomy.

Starting from the context of qualitative research, Moreira (2011) says that the interest of this type of investigation is anchored in the elucidation and exposition of meanings by the researcher to the meanings people attribute to events and objects in a social context. The research methodology is guided by Content Analysis (Bardin, 2016) and went through the organization phases: pre-analysis, material exploration and treatment of results and interpretation.

We analyzed articles published in the main periodicals in the area in Brazil: Revista Latino-Americana de Educação em Astronomia; Brazilian Notebook of Physics Teaching; Brazilian Journal of Physics Education; Science & Education - UNESP; Science & Teaching - UNICAMP; Essay: Research in Science Education - UFMG; Research in Science Teaching - UFRGS; Brazilian Journal of Research in Science Education – ABRAPEC. In all, 220 works on Astronomy Teaching were analyzed.

In the pre-analysis stage, we performed a manual search on the websites of the journals themselves and collected all articles available until the end of 2020 and that presented a study within the astronomy theme indicated in the titles, abstracts or keywords. With this set of 220 articles, we organized the material using a reference manager and then skimmed all the works, selecting those developed in the context of basic education, excluding articles on hard astronomy. In the next phase, designated as material exploration stage, 67 articles were read in full, in search of arguments aimed at Basic Education and discarded those aimed at non-formal and informal education; later, we carried out an exhaustive reading of the excerpts that had the justifications present in the articles. Finally, in the stage of processing the results and interpretation, we analyzed the justifications found and categorized them. We use four major categories built from a rereading of a previous work (LEITE; SOLER, 2012): the awakening of feelings that astronomical themes can provoke in different audiences; the socio-historical-cultural importance attributed by humanity to Astronomy; the possibility that this Science can broaden the worldview and raise awareness on issues such as environmental preservation and citizenship; and the ability of Astronomy to interrelate with other areas of knowledge (interdisciplinarity).

Among the considerations, it can be indicated that, although there is an increase in the number of researches that seek to justify the presence and importance of Astronomy Teaching in Basic Education, the arguments pointed out remain similar to those found by Soler (2012). In addition, the justifications continue to be presented without theoretical foundation, that is, in a superficial way, which reveals the need for research dedicated to investigating these arguments in greater depth.

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Discussion summary

The talks from our experts[2] instigated some key discussion points that were unpacked during the live panel. The overarching themes can be summarised into: Fostering collaborations between astronomers, astronomy educators and astronomy education researchers; tips for those new to AER; ways to inspire teachers who may not be interested in participating in research projects, and to foster collaborations with teachers; navigating the Ethics landscape especially across countries; and the nuts and bolts of the Astronomy Education Journal.

Janelle Bailey's wise statement "there is no point re-inventing a flat tire" provided a fundamental insight. Although there are resources, when starting out (or even if you are already) in AER, it is prudent to collaborate with individuals who have expertise in various aspects. For example, have a teacher on your team who can engage with not only the excited teachers ("learners"), but also those not interested ("tourists and prisoners"). One way to foster collaborations with teachers is to approach pre-service teachers via the relevant universities and/or colleges, because early engagement can potentially sow the seeds for long-term collaborations.

Although some countries/institutions may not have an ethics board, it is vital to understand that we are dealing with "autonomous human beings", and that we are not doing research on people but with people. Therefore, collaborating with researchers who have access to an ethics board can provide an objective assessment and guide the ethical considerations of your project, rather than trying to build your own ethics board.

[2]Sanlyn Buxner joined us as a guest expert for the second live panel session.

Astronomy Education with Authentic Data

Session organiser: Niall Deacon, Office of Astronomy for Education/Max Planck Institute for Astronomy, Germany

Session overview

Over the past seventy years, astronomical surveys have accumulated huge amounts of data about the sky. This includes a wide range of wavelengths, time domain data allowing the study of motion & variability, and even non-electromagnetic signals such as gravitational waves or cosmic rays.

Now this wealth of authentic data is being used to introduce school students to the universe. This could include curated educational datasets from remote observatories, training teachers to use survey data in projects with their students or incorporating authentic data into planetarium shows for schools.

This session included speakers who have worked to incorporate survey data into resources for schools. They talked about their own projects, but more importantly shared the lessons they learned along the way, allowing you to learn from their experiences when building your own activities.

What You Need to Know about the NASA/IPAC Teacher Archive Research Program (NITARP)

Speaker: Luisa M. Rebull, Caltech-IPAC, USA

NITARP, the NASA/IPAC Teacher Archive Research Program gets teachers involved in authentic astronomical research using the same online astronomy data archives as professional astronomers. We partner small groups of educators with a professional astronomer mentor for a year-long original research project. The teams experience the entire research process, from writing a proposal, to doing the research, to presenting the results at an American Astronomical Society (AAS) meeting. This talk will provide an overview of the program, highlighting use of real data in astronomy educator professional development experiences.

Talk link: https://youtu.be/MLSFNozOZ_c

There are a lot of programs getting teachers in touch with real astronomy data. I find it useful to think of organizing all these programs as a funnel, where the most interested people move down the funnel (see Rebull 2018a for more discussion). The programs that reach the most people are at the broadest part of the funnel, and people just need a web browser and an internet connection to participate. The most interested people might be enticed to participate in working more directly with real data, or even contributing their own data. Very few people end up near the bottom of the funnel, doing original research.

"Everyone should know" that there are a lot of programs populating the funnel (listed here: https://nitarp.ipac.caltech.edu/page/other_epo_programs), and all levels of the funnel are important! Programs at each level have vastly different goals and audiences. NITARP (http://nitarp.ipac.caltech.edu), the NASA/IPAC Teacher Archive Research Program, lives near the bottom of the funnel.

In NITARP, teachers get an authentic research experience using real data and tools. We model the entire research process from proposal to results in a year. (See Rebull et al. 2018b for more information about NITARP.) We have been operating since 2005, so we have refined our procedures (and continue to do so). Participants must be US based. They get three trips out of the program: (1) an American Astronomical Society (AAS) meeting to get started on their project and see how the AAS works; (2) 3-4 days at Caltech/JPL to work on their project; (3) back to the AAS to present results. NITARP pays for up to 2 students per teacher for the second two trips. All NITARP teams must use data housed at IPAC, but fortunately there are quite a bit of ready-to-use data in the archives, with tools getting better all the time.**"Everyone should know"** that teachers and students get really excited about working with real data and tools.

"Everyone should know" that teachers do not have as much control over their computers as astronomers do, and moreover use Windows or Chromebooks. So, we use online tools like those at IRSA (`http://irsa.ipac.caltech.edu`) and Excel (because it is widely available). "Everyone should know" that few teachers pre-pandemic had experience working remotely, but our alumni did, and they felt like they had an advantage over other teachers!

"Everyone should know" that partnerships only work if both partners get something out of it. (See, e.g., "The Power of Partnerships: A Guide from the NSF Graduate STEM Fellows in K-12 Education Program".) In NITARP, scientists learn better how to teach, and teachers learn how research works and how to get data. **"Everyone should know"** that working with teachers substantially leverages your influence, because if you change the way that teachers think, you change everyone they teach thereafter, from students in their own classes, to after-school clubs, to peer teachers in the break room.

"Everyone should know" that teachers rarely get to collaborate with other teachers, much less people in other states. Teachers often work in isolation. Astronomers collaborate easily and often. Teamwork and sharing skills are an important 'product' that NITARP gives these teachers (see Rebull et al. 2018c). **"Everyone should know"** that teachers have not been on "research trips" like astronomers. The summer trip is based on that, and it is a new, very intense experience for participants. "Everyone should know" that teachers are being asked by the Next Generation Science Standards to teach in ways that they themselves were not taught. They crave training on how to do this and how to use real data. (See, e.g., Rebull et al. 2018d.) NITARP meets that need. As a result, NITARP has 5x oversubscription, which is rare in education.

"Everyone should know" that we really do publish, in major journals, results of NITARP teams' work. To date, we have 70 science posters, 74 education posters, 8 refereed astronomy journal articles, & 6 refereed education journal articles. All are on the NITARP website.

"Everyone should know" that teachers are used to literally being the smartest person in the room when it comes to their subject matter. Astronomers, indeed all scientists, feel stupid all the time. (We share Schwarz 2008, which is entitled, "The Importance of Stupidity in Scientific Research.") Teachers are also not used to learning at this level, rapidly, much less in tandem with their students. NITARP teachers learn how to learn in a new way. (See Rebull et al. 2018c.)

"Everyone should know" that teachers tell us their experience in NITARP is "life changing" (see Rebull et al. 2018c), so we must be doing something right!

There are a lot of programs getting authentic astronomy data into the hands of teachers and students, but few that do research with the data. Teachers and students are more than capable of using research-grade data and tools to conduct authentic research with a mentor; they will rise to high expectations. They get really excited about doing real research! And, despite the learning curve, they love using research-grade software & data. This requires a long-term ($\approx$year at least) commitment to the program; it is a large investment of time per participant, but it can change teachers' lives. Educators continue after NITARP to incorporate authentic data and experiences into their classroom using skills they learned from us.

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Rubin Observatory's User-Friendly Approach to Working with Authentic Data

Speaker: Ardis Herrold, Education Specialist for Vera C. Rubin Observatory, USA

Working with authentic data can be an engaging experience. Historically, the challenges with accessing, querying, and analyzing datasets can cause significant time and technology issues. Additionally, novice learners often struggle to develop quality research questions and the skills to explore data. These constraints often limit the types of students or classes that can successfully work with authentic data. Rubin Observatory's desire is to make data accessible to all students and teachers in a way that honors the time and technology constraints of the classroom, and is designed to match the appropriate reasoning level and common learning challenges of students who are novice learners. We introduce interactive online investigations designed to increase accessibility.

Talk link: https://youtu.be/-7ewXhW9gQk

Rubin Observatory will begin a sky survey in early 2024, covering the entire visible sky every three to four nights with wide field, high resolution images. Over the first ten years of the survey, co-added images will reveal billions of previously undetected faint objects. For this reason, the survey is sometimes described as "wide, fast, and deep".

The Education and Public Outreach team at Rubin Observatory has been working to design ways to allow non-scientists to explore data. One aspect of this has been developing and testing classroom investigations that will utilize Rubin data once it becomes available. We aim to apply the "wide, fast, deep" method to our education audience: Provide access to a wide diversity of learners, by designing means to quickly access and analyze data, and create experiences that lead students to a deep understanding.

Working with authentic datasets comes with its own set of challenges, which historically has discouraged teachers and students from using them. Our goal is to make data access and analysis so user-friendly that it is accessible to most students and teachers, instead of only those in advanced classes, or in classes with no curricular or time constraints.

To make data user-friendly, we identified and addressed the issues facing teachers and students in a typical classroom. We chose to focus on topics that are typically covered in an introductory astronomy course or unit, and designed the investigations to support novice learners.

We recognize three common challenges for teachers:
- A limited amount of time to prepare and teach lessons
- School technology and infrastructure issues
- Feeling under-prepared to work with authentic data

Students introduce additional considerations:
- A wide spectrum in background knowledge and skills (math, reading, writing, data literacy) exist within the same classroom
- Some students lack confidence in their ability to be successful in math and science

Traditional access to data often requires substantial time and training. There may be firewalls to pass through, or constraints on the size of a data download. Selecting datasets may involve learning a query language, and/or teaching it to students. The school technology infrastructure may not support downloading data, or installing specialized software for analysis on a series of computers.

We have designed a way to process data in the cloud by using online tools that are embedded within each investigation. All that is needed is access to the internet through any modern browser.

Real data are messy, and often need to be processed in order for a general trend to become obvious. We have done necessary reductions in the data and curated data sets where necessary in order for novice learners to be able to effectively analyze them. Where possible, we have designed guided practice with feedback before students begin to analyze their own data.

To assist students with diverse needs, we present data using clearly-designed plots, data visualizations, and tools that span multiple types of representations: images, interactive histograms, 3D spatial analysis tools and mathematical relationships. Embedded calculators do the arithmetic, so that students have more time to focus on computational relationships and quantitative reasoning. Narratives are concise and avoid the use of unnecessary jargon.

Teachers are likewise supported with an extensive teacher guide, assessments and additional instructional materials, so that they feel sufficiently prepared to deal with the nuances of working with authentic data.

Finally, we have given much thought to the instructional design that empowers students to unpack and make sense of new complex ideas. Some interactive tools are designed to help students confront and explore learning confusions or misconceptions. We suggest questions that lead students through a sequenced reasoning process.

The takeaway message is that making data access and analysis easy does not mean it lowers the degree of intellectual engagement or rigor. Rather, by removing distractions and unnecessary data processing and analysis tasks, students have more time and confidence to actively engage in learning, to explore their unique data set, converse and collaborate with peers, and develop robust conceptual models that lead to deep learning and an enthusiasm for exploring the cosmos.

Using Radio Astronomy Data to Engage and Challenge Students

Speaker: Robert Hollow, CSIRO, Space and Astronomy, Australia

Collaborators: G. Hobbs (CSIRO), L. Toomey (CSIRO), S. Dai (School of Science, Western Sydney University)

Using authentic data, especially that obtained directly by students is an effective way to engage their interest and develop questioning and analytical skills. Whilst there are many excellent examples of programs using optical data, astronomy is a multi-wavelength discipline. Using radio astronomy as the context we explore a variety of ways in which students can obtain, be presented with and use data. Flexibility in program design allows students to be engaged in a one off experiential engagement or use in short-term or more open-ended student investigations. Examples of these are presented and advantages and pitfalls discussed. With the massive increase in data rates with new facilities there are exciting opportunities in coming years for astronomy education projects across wavelengths.

Talk link: https://youtu.be/u7AuXul0n2U

Whilst there are many excellent examples of educational programs using optical data, astronomy is a multiwavelength discipline. Using radio astronomy as the context, we explore a variety of ways in which students can obtain, be presented with, and use data. Activities can range from simple pen and paper exercises, building simple radio telescopes, or using major facilities remotely and online tools to view and analyse data. With the massive increase in data rates with new facilities there are exciting opportunities in coming years for astronomy education projects across wavelengths.

Radio astronomy has the benefit of large (massive) data sets, many of which are freely available online. As radio telescopes can operate day and night, they are ideal for school use whenever suits the school. Recent developments allow simple radio telescopes to be built at low cost within schools. Challenges exist in that radio data is generally less"obvious" than optical data. It may have file formats that require professional research level software, UNIX-based, that are difficult for school students to engage with. File sizes may also be massive.

Simple activities:

1. Use a transistor radio, tuned between AM stations. To detect Radio Frequency Interference (RFI) from sources such as laptop screens, phones, power points. Can map out sources of RFI in the environment. Discuss how a transistor radio is basically a radio telescope – antenna, amplifier, output source (speaker).

2. Colouring in image maps – simple paper examples (https://edu.inaf.it/astrodidattica/immagine-radio-primarie/) or use coding with colour palettes (https://play.inaf.it/la-galassia-m77/) to illustrate images of, e.g., radio galaxies.

3. Worksheets with data and explanations, can target different levels, e.g., Weighing a Galaxy Activity at https://www.icrar.org/outreach-education/resources/

Online Observatory and Virtual Sky Tours:

1. ALMA Walk-throughs with Google Street View: https://kids.alma.cl/walk-through-alma-with-google-street-view/

2. Murchison Radio-astronomy Observatory Virtual Tour: https://virtualtours-external.csiro.au/MRO/

3. Gleamoscope (uses GLEAM low frequency survey from Murchison Widefield Array, MWA): https://gleamoscope.icrar.org/

4. ASKAP RACS Virtual Sky Tour: https://www.atnf.csiro.au/research/RACS/RACStour/index.html

5. EMU Pilot Survey: http://emu-survey.org/pilot/

Citizen Science:
Examples using radio data in Zooniverse (https://www.zooniverse.org/projects):

1. Radio Galaxy Zoo LOFAR: uses LOFAR data to search for supermassive black holes (https://www.zooniverse.org/projects/chrismrp/radio-galaxy-zoo-lofar)

2. Bursts from Space uses data from CHIME telescope to search for Fast Radio Bursts (FRBS) (https://www.zooniverse.org/projects/mikewalmsley/bursts-from-space)

Small Radio Telescopes:

- Dipoles antenna, e.g., Radio Jove (https://radiojove.gsfc.nasa.gov/)
- Satellite dish, e.g., Itty Bitty Telescope (https://www.gb.nrao.edu/epo/ibt.shtml)

Software Defined Radios (SDRs):

Cheap Software Defined Radios (SDRs) replace purpose-built radio receivers and allow users to connect an antenna to a computer to detect and view radio waves from a variety of sources. They are excellent for viewing Radio Frequency Interference (RFI). Connect to a feedhorn-waveguide-low noise amplifier (LNA) and a software backend, radio signals from space can be detected, giving a radio telescope for less than $200. Students can experiment with feedhorn and waveguide designs, time of day, cooling the LNA or removing it. Software is free.

Examples of Programs Using Professional or Remote Facilities:

1. Pulsar Search Collaboratory: http://pulsarsearchcollaboratory.com/
2. Goldstone Apple Valley Radio Telescope (GAVRT): http://gavrt.lewiscenter.org/
3. INAF FRB Hunting: https://www.youtube.com/watch?v=4yghT3ZMzbU
4. VSSEC Radio Astronomy - The Invisible Universe: https://www.vssec.vic.edu.au/radio-astronomy-the-invisible-universe/
5. CSIRO's PULSE@Parkes: https://research.csiro.au/pulseatparkes/

There are multiple ways to engage students with radio astronomy from simple activities to using major research facilities. Opportunities for browser-based, archived, hands-on telescope construction, real-time observing.More user-friendly tools would be helpful. Massive data sets coming, e.g., ASKAP, SKA. Have an idea? Let's talk!

Using Real Data to Teach Astronomy

Speaker: Fraser Lewis, Faulkes Telescope Project and National Schools' Observatory, UK

I will present examples of IBSE (Inquiry-Based Science Education) activities, designed to be "teacher-free", and used as extended projects for students of astronomy and space science. Each project uses data and resources from the Faulkes Telescope Project and the National Schools' Observatory. Both projects provide free access via the internet to 2-metre robotic telescopes. These resources are based on open clusters and exoplanets and also include a Citizen Science type project using data from Type Ia supernovae, all of which provide an insight into the scientific process. Here, users perform browser-based photometry (using JS9) on images to add additional data-points to the Hubble Plot, enabling them to measure the expansion rate and age of the Universe.

Talk link: https://youtu.be/QuzvCVxY65w

Based in South Wales, the Faulkes Telescope Project (FTP, http://www.faulkes-telescope.com/) provides free access, via both queue-scheduled and real-time observations, to a global network of 2-metre, 1-metre and 0.4-metre robotic telescopes. FTP was originally conceived by Dr Martin 'Dill' Faulkes to promote the teaching of STEM through the medium of astronomy in schools in the UK and in Ireland.

The network contains two 2-metre f/10 Richey-Chretien telescopes, located on Haleakala on the island of Maui, Hawai'i (FT North; FTN) and at Siding Spring in New South Wales, Australia (FT South; FTS). In 2006, FTN and FTS were bought by Las Cumbres Observatory (LCO) and since then, FTP has been an educational partner of LCO.

The LCO network now has a further nine 1-metre telescopes along with ten 0.4-metre telescopes. FTP provides free access via LCO's queue-scheduler and exclusive real-time access to 2-metre and 0.4-metre telescopes in both Hawai'i and Australia. This access is for educational users, predominantly in the UK and Ireland, but also including educators and schools from other parts of the World.

FTP also provides resources (http://resources.faulkes-telescope.com/) with suggestions on suitable targets, when they are visible, how to analyse the data and access the data archive.

The National Schools' Observatory (NSO, http://www.schoolsobservatory.org.uk/), allows observing on the 2-metre Liverpool Telescope (LT). The LT is based at the Instituto de Astrofísica de Canarias (IAC) at Observatorio del Roque de los Muchachos on La Palma in the Canary Islands, Spain. The LT features a broader range of instrumentation than FTN/FTS and is run by the Astrophysics Research Institute (ARI) at Liverpool John Moores University.

Established in 2004, the NSO provides schools in the UK and Ireland with access to the Liverpool Telescope through a guided observing system, using 10% of the LT's time. Its website contains astronomy-related content, news and learning activities. With over 4,000 users, the NSO allows non-UK/Ireland based schools and teachers to register by granting free access to both the observing portal and resources.

The Activities

The first activity (http://www.schoolsobservatory.org.uk/discover/projects/clusters/main) was created in 2017. It allows students to learn about open clusters, the life cycle of stars and the Hertzsprung-Russell diagram as well as the technique of photometry. Including screenshots and screencasts, this activity teaches students how to analyse their data using Makali'i (https://makalii.mtk.nao.ac.jp/) and e.g., Microsoft Excel. They are then encouraged to upload their results in the form of a colour-magnitude diagram with the aim of encouraging them to discuss their findings with other students.

Students can choose between 28 datasets (Bessel- B and -V images from FTP) but it is also possible for students to perform their own observations of an open cluster of their choice with FTP or NSO. There is also the opportunity here to use the FLOYDS (FTN/FTS) or SPRAT (LT) spectrographs to follow-up any object of interest, such as outlier supergiant stars or those stars which appear to be very red or blue. A second activity (https://www.schoolsobservatory.org/discover/projects/exoplanets/main) focuses on population studies of exoplanets from the exoplanet.eu website. Students explore the properties of exoplanets (e.g. radius, mass, orbital period) and can search for any correlations between these properties. The activity includes information on selection effects, which in turn can lead to incorrect conclusions.

Finally, I present a third activity, which has been created as a crossover between IBSE and Citizen Science (https://www.schoolsobservatory.org/discover/projects/supernovae). It uses data collected by FTP from Type Ia supernovae as discovered by Gaia Alerts (http://gsaweb.ast.cam.ac.uk/alerts/alertsindex). Users are instructed on how to perform photometry using an online browser-based photometry tool called JS9. Using robotic telescopes, users can add additional data-points to the Hubble Plot, giving them ownership of their data and enabling them to measure the expansion rate and age of the Universe.

Advantages and Disadvantages of IBSE-type Activities

We believe students using these activities can gain an insight into the scientific process and the collaborative nature of science and in time, will go on to develop their own projects and make their own suggestions for extensions activities. We note that these projects require a level of background information and can present problems around software installation on different platforms and operating systems. Moreover, real data can introduce further obstacles over the sample datasets that we present in the activities.

We will create other IBSE-type resources and intend to base these resources on topics such as variable stars, black holes and spectroscopy. We hope we can encourage interested parties to contact us with feedback and suggestions on both current activities and future direction.

Co-creation 3.0: Taking the Development of Astronomy Education Resources to the Next Level in the Project Stargazing Live!

Speaker: Joanna Holt, IAU-OAE NAEC, Netherlands Research School for Astronomy (NOVA), The Netherlands

Collaborators: Joris Hanse (NOVA), Marieke Baan (NOVA, IAU-OAE NOC), Paul Groot and Steven Bloemen (Radboud University, Nijmegen, The Netherlands)

Traditionally, the majority of astronomy outreach and educational work has been undertaken by scientists with an interest in science communication. However, recent research has shown the importance of actively including teachers in designing and testing new educational materials. In this talk we will present a new project which takes co-creation to a new level. Stargazing Live! is a collaboration between the NOVA education and outreach group and the MeerLICHT and BlackGEM telescopes. It combines the expertise of 1) astronomy outreach and education professionals, 2) physics teachers and 3) scientists to create an exciting and innovative education package bringing semi-live telescope data into the classroom.

Talk link: https://youtu.be/ZTTCk0xoIxA

Introduction to the project Stargazing Live!

The Stargazing Live! project will bring semi-live data (e.g. from the previous night) from the MeerLICHT (www.meerlicht.org) and BlackGEM (www.blackgem.org) telescopes into the classroom. These small optical telescopes are designed to observe transients in the night sky and in the case of BlackGEM, to search for the optical counterparts of gravitational wave detections. Each night, the data is uploaded to Nijmegen where it is processed automatically.

This project aims to create a suite of educational resources suitable for upper secondary school physics students (16-18 yrs; pre-university education). The main product is a new interactive planetarium show for the NOVA network of mobile planetariums, which visit schools across the Netherlands. In addition to covering advanced topics in astrophysics linked to the scientific goals of the telescopes, the show will include real data projected onto the dome. The project will also develop complementary classroom activities, again using real data as much as possible. There will be a short activity suitable for an individual lesson and a more in-depth activity suitable for student projects. In addition, the project output has the following educational goals: 1) to be inspirational; 2) to be scientifically accurate and show-case cutting-edge research; 3) to be linked to the curriculum (knowledge & science skills) and 4) to be rigorously tested.

Co-creation of astronomy education resources

Traditionally, many educational resources and activities have been developed by astronomers with an interest in outreach. The goal is to create something fun and inspiring, or to promote the scientist's research area to a wider audience. However, the creation was often the focus with little structural testing in schools or feedback from teachers. Didactical tips for teachers or a link to the curriculum were rarely included. More recently, there has been a shift towards 'co-creation' whereby teachers are more involved in the development process, although the level of involvement of teachers is variable. Platforms such as `astroedu.org` have actively encouraged the involvement of teachers - publication on `astroedu.org` requires an activity to be tested in at least one classroom and all activities are 'peer-reviewed' whereby the content is checked by a teacher and a scientist.

Co-creation 3.0 in Stargazing Live!

We have chosen to title this work co-creation 3.0, due to our requirement to involve *three* key areas of expertise at all stages of our project: astronomy, communication/outreach and education. Our core team already includes a broad set of these skills with team members who are professional astronomers, astronomy communication and outreach professionals, a planetarium specialist and a former astronomer with formal education experience.

We will boost this expertise with input from physics teachers at all stages of our project, from a wide-scale survey and focus groups during the *pre-development phase*, to testing and feedback from teachers (including during a teacher training event) during the *main development phase* to extensive feedback and testing during the *post-development phase*. The post-development testing will last a full year.

Initial Teacher Feedback

Astronomers and astronomy education and outreach professionals are often in contact with one or more highly-engaged teachers. These teachers typically have a strong personal interest in astronomy and are often avid amateur astronomers. As such, this group of teachers often play a large (or main) role in providing advice and feedback regarding resources.

In our survey and focus groups we talked to a broader range of teachers and the results were not always what we were expecting. Highly-engaged teachers are typically keen to gain access to new results and insights, have activities based on real data and see the role of projects like Stargazing Live! to inspire their students. However, the majority of responses suggested that a strong link to the curriculum is the key and the main driver for teachers in deciding which activities to give to their students. Below is the summary of a few key differences.

- Topics: cutting-edge astronomy
  Activity size/length:
  - final year project (>20 hrs)
  - in-depth research with real data
  Quote: 'Leave the teaching to us, you inspire them with cutting-edge astronomy'.

- Topics: gravity & electromagnetic spectrum
  Activity size/length:
  - short (<30 min)
  - support curriculum
  Quote: 'My program is too full for activities which are only nice or inspiring, but if I think they will help my students do better in the exam, there is always time'.

Astronomy education resources should be created by *astronomy education and outreach professionals*, with significant input from both *astronomers* and *teachers*. The ideal development team will include expertise in all of these areas with further help coming from the engagement of a *broad group of teachers* in all (*pre-*, *main* and *post-*) *development* stages.

Astronomy Data Visualization with WorldWide Telescope and Glue

Speaker: Patricia Udomprasert, Center for Astrophysics | Harvard & Smithsonian, USA

Collaborators: Alyssa Goodman (CfA), Harry Houghton (CfA), Peter Williams (CfA, AAS), Jonathan Carifio (CfA), Nicholas Earl (University of Illinois Urbana-Champaign), Mary Dussault (CfA), Susan Sunbury (CfA), & Jonathan Foster (CfA)

We showcase astronomy curricula that engage learners with authentic data through the use of powerful open-source tools, WorldWide Telescope (WWT) and glue. WWT is a rich visualization environment that functions as a virtual telescope, allowing anyone to make use of real astronomical data to explore and understand the cosmos. WWT users navigate through 3-dimensional and 2-dimensional views of planets, stars, and galaxies, giving them a better mental model of our universe. Glue is a suite of modular tools for multi-dimensional linked-data exploration that allows users to visualize relationships within and among related datasets.

Talk link: https://youtu.be/vSWxw8dMjko

Data visualization with WWT:

In this presentation, we briefly present features in WWT that allow users to view astronomical images in a contextualized view of the night "sky." We provide information about three online interactives built using the WWT web engine and demonstrate usage of the Solar System Explorer interactive. Key features include being able to fly to any major object within a 3-D view of the solar system, scale the planet sizes to their "true" sizes or enlarge them, and speed up time to make solar system motions easier to visualize. WWT's open-source web engine allows the curriculum designer/developer to identify key views and features within WWT that we want the learner to focus their attention on, so we can provide a customized WWT experience targeted to those pedagogical goals. Links for the WWT resources are provided below.

Data visualization with glue and WWT:

We provide a brief overview of how glue is used to visualize data in a research context and how the Cosmic Data Stories team is bringing that functionality, along with WWT, to online interactives that will allow the public to practice data science skills. We share screenshots from the prototype Hubble Data Story and discuss highlights of this activity, which is intended for use in high school and introductory college level classrooms. Students will explore a sky view in WWT to select galaxies they wish to "observe," and will use spectra and imagery data from the Sloan Digital Sky Survey to measure their galaxies' velocities and distances (using a standard ruler technique). After completing measurements for about five galaxies, the students will visualize their velocity and distances in a scatter plot using glue and will fit a line to their data to obtain a value for the Hubble constant and age of the universe. They will then aggregate all the data from their class to obtain Hubble and age values using the larger data set. They will be able to view the distribution of age estimates from individual students who have used the Hubble Data Story and compare that with the distribution of age estimates from entire classes, which will be significantly narrower, to obtain an intuitive understanding of why using a larger data set can reduce random uncertainties in a measurement. Finally, students will view their results in conjunction with historical and modern science data, including Hubble's own 1929 Hubble plot, to see how their own measurements are contextualized within a broader scientific story. Links to glue and the CosmicDS website are provided.

WorldWide Telescope links:

- WorldWide Telescope: `worldwidetelescope.org`
- WWT Ambassadors Educational Resources: `wwtambassadors.org/educational-materials`
- WorldWide Telescope Interactives: `wwtambassadors.org/astronomy-interactives`
  Solar System Explorer: `https://wwtambassadors.org/solar-system-explorer`
  Star Life Cycle: `https://wwtambassadors.org/Life-Cycle-Of-Stars`
  Hubble Law & Big Bang: `https://wwtambassadors.org/Hubble-Big-Bang`
- GitHub repository for WWT Interactives: `http://github.com/wwt-ambassadors`

glue & Cosmic Data Stories links:

- glue: `glueviz.org`
- Cosmic Data Stories: `cosmicds.cfa.harvard.edu`

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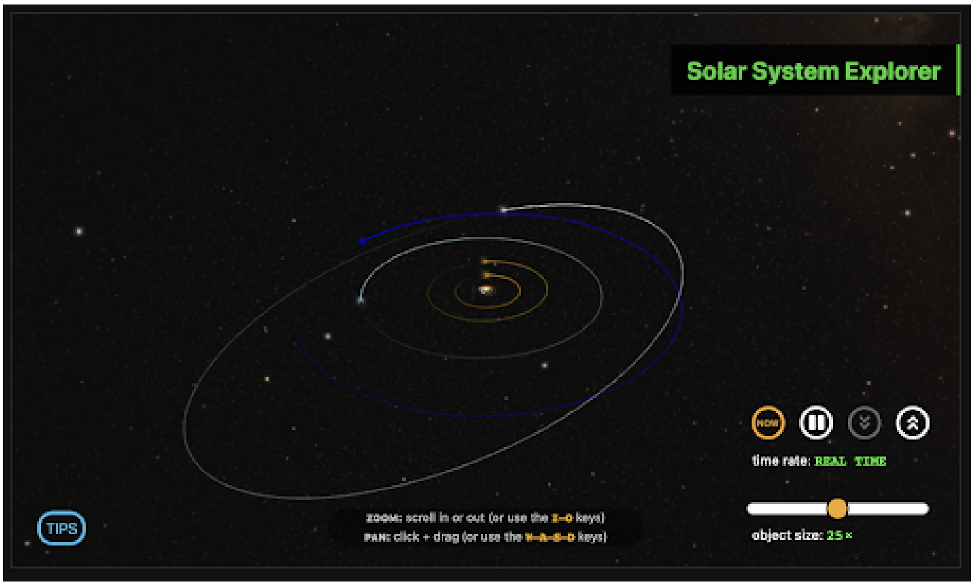
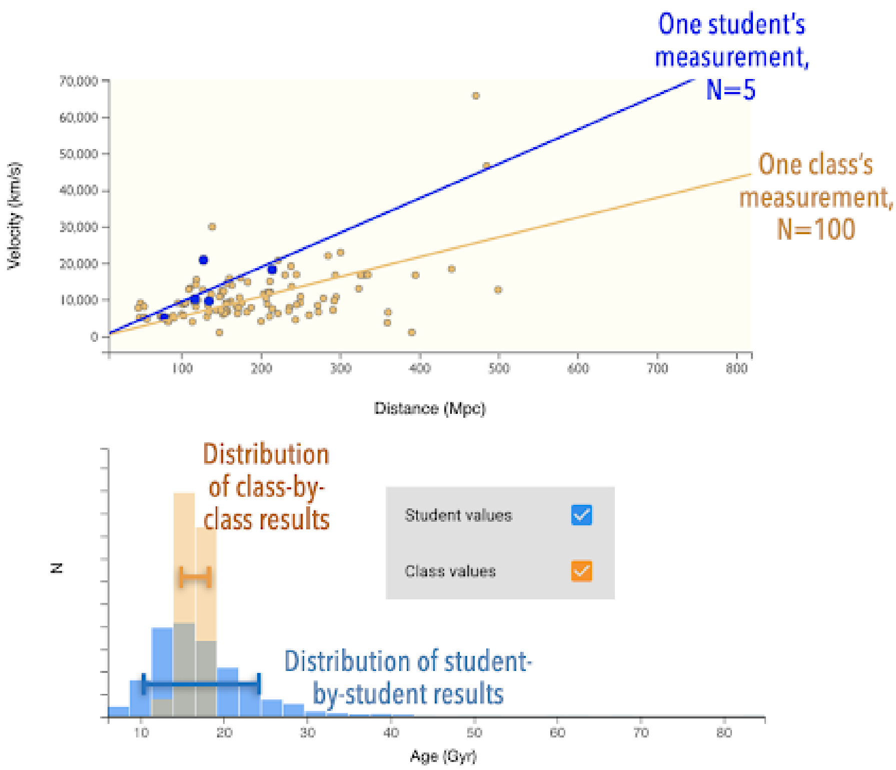


Screenshot from the WWT Solar System Explorer



Screenshot from the prototype Hubble Data Story

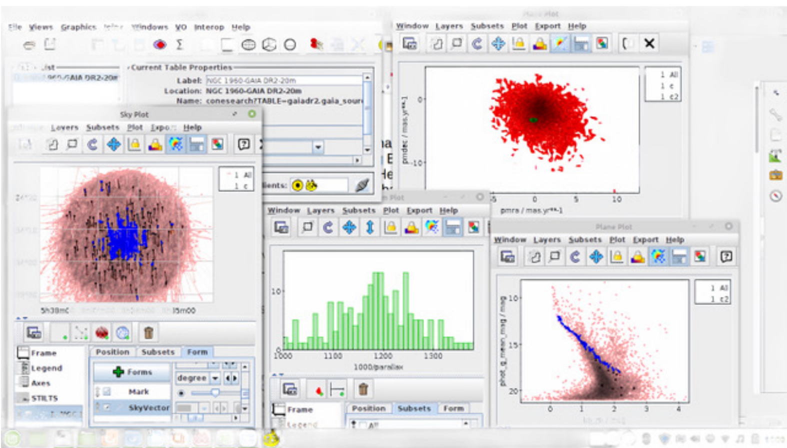
GaiaDemos@School

Presenter: Priya Hasan, Maulana Azad National Urdu University, Hyderabad, India

Gaia with its unprecedented accuracy has revolutionised our understanding of the Milky Way. It not only provides a three dimensional picture of our universe, but also shows its dynamic nature. Using tools like TopCat and ESASky, we can demonstrate the school students the power of Gaia and change misconceptions of students of a static never-changing universe. Data has the potential to convey and convince young inquisitive minds.

Poster link: `https://youtu.be/0dbEz0moadU`

Gaia is an ESA astrometric and photometric survey that studies a billion stars of our Galaxy. We shall study the importance of using Gaia data to study stars and their three-dimensional distribution in the galaxy. A constellation is a group of stars that appears to form a pattern or picture like Orion the Great Hunter, Leo the Lion, or Taurus the Bull. Constellations are easily recognizable patterns that help people orient themselves using the night sky. There are 88 recognised constellations. These stars may not be at the same distance and may not be gravitationally bound. We can demonstrate to students the association of stars in a constellation. We shall demonstrate the use of TopCat to download and plot Gaia data for the analysis of the star clusters. We can also use ESASky to help students visualize data.



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- Hasan P., Hasan S.N., Astronomy Education in Covid Times, arXiv:2104.06305

Connecting to Learn Together

Presenter: Carolina Escobar, Galileo Teacher Training Program, Colombia

Our approach is educational, targeting mainly elementary, middle and high school teachers and members of astronomy communities as well, who wish to expand their knowledge and skills through the Project Based Learning methodology, using the robotic telescope network of Las Cumbres Observatory as well as free use resources during our workshops. Participants provide input from their experience, actively participate in the observations programming and analyze the obtained results, which empowers them during the workshop by applying the knowledge acquired. This motivates them to apply the knowledge acquired in their classrooms, showing their students that doing science has a deep relationship with their personal learning.

Poster link: https://astro4edu.org/siw/p38

Helios is an initiative of the Galileo Teacher Training Program and started its operation in early 2018.

Helios conducts face-to-face and virtual outreach activities focused on teachers, astronomy associations and for the general public, because it is aligned with the United Nations Millennium Development Goals such as reducing the knowledge gap and increasing the participation and inclusion of women.

Helios GTTP group has been a member of the LCO's Global Sky Partner program since 2019, when the proposal Study of Transient Phenomena in Solar Stars was presented, to develop workshops with PBL (Project-Based Learning) methodology focused on teachers and people interested in astronomy, so that these in turn, can transmit the knowledge to their students and thus increase interest in astronomy. With its admission to the Global Sky Partner program in 2019, Helios GTTP was the first Colombian group to participate in the Global Sky Partners program of Las Cumbres Observatory (LCO).

HELIOS GTTP has also participated in national and international conferences where the advances and results of the workshops are presented, and in this way has achieved such an interest in these Project-Based Learning workshops that some of its participants have applied to the LCO Global Sky Partners with their own projects. To date, Helios GTTP has made 438 observations using the robotic telescope network during its workshops. The direct and indirect audience of its workshops and outreach activities is more than 150 people.

We have contacted the Office of Astronomy for Education in Colombia, the Global Office of Astronomy for Development and the Office of Astronomy for Development in North America, who have been informed of the intention to expand HELIOS GTTP coverage to impact the Spanish-speaking community. We are working towards constructing a network that will help achieve the desired vision for HELIOS GTTP.

Discussion summary

We were joined by our speakers for two live discussion panels. One important topic that was discussed was how much context to include in an activity. What information should be included to give students the right amount of knowledge to carry out an activity and what unnecessary, possibly confusing information to exclude. This section of the discussion also touched on how best to curate datasets so that students are able to carry out their activities without getting lost. This discussion also included how linked visualizations can be used to bring in extra information both to allow students to explore the data more, or to counteract misconceptions.

The panel also discussed how to build activities to match curricula. This can often be a problem as curricula can change within and between countries. The panel discussed how activities can be based on common elements found across curricula.

The panel also discussed the importance of working with a wide range of teachers to learn what sort of activities would be most useful in the classroom.

Citizen Science

Session organiser: Asmita Bhandare, Office of Astronomy for Education, Germany and CRAL/ENS Lyon, France

Session overview

In the last few years, several citizen science projects have been very successful in introducing and engaging the public in authentic research. Citizen scientists continue to be a valuable asset in helping scientists tackle large data sets and extract useful information to solve some exciting mysteries of the universe.

This session included contributions from several ongoing citizen science initiatives across the globe, with an aim to encourage participation in various projects and even motivate anyone who wants to set up their own citizen science projects.

The keynote speaker, Molly Simon introduced the concept of citizen science and highlighted the past, present and future projects on Zooniverse, which is the largest online platform for citizen science. Ananda Hota shared his experience on establishing the first ever Indian citizen science project - RAD@Home, involving several research institutes and successfully engaging the public in various research projects. Masayuki Tanaka introduced Galaxy Cruise, a citizen science project run in Japan, which is an exciting opportunity for the public to use imaging data taken with the Subaru Telescope to help identify interacting galaxies. Marc Kuchner gave an overview of NASA's growing citizen science program and discussed the lessons learned from various projects. Pamela Gay emphasized on providing a supportive, diverse and inclusive community for anyone who wants to be a citizen scientist and shared insights on ways of adapting this in citizen science initiatives.

Lastly, four additional citizen science projects were highlighted as poster contributions about monitoring meteor shower activities using machine learning (by Siddha Ganju), using citizen science as a tool for science popularization (by Felipe Sérvulo Maciel Costa), tracking effects of the solar eclipse on GPS signals (by Carla Hernández), and a project involving the science of gravitational wave detectors (by Francesco Di Renzo).

Why Citizen Science: Unlocking the Potential of People-Powered Research

Speaker: Molly Simon, Arizona State University, USA

Collaborators: Laura Trouille (Adler Planetarium, Northwestern University), Chris Lintott (University of Oxford), Edward Prather (University of Arizona), Isaac Rosenthal (UMass - Boston)

The vast wealth of astronomical datasets produced by modern surveys - and our shared access to the sky - make astronomy a natural home for citizen science projects which provide participants with authentic experiences of scientific practice. In this talk, I will draw on examples both historical and contemporary from the Zooniverse, to ask what makes an effective citizen science project and how such projects can be incorporated in broader engagement programs. I will conclude by highlighting the new classroom.zooniverse effort to bring data-rich, citizen science-based, classroom experiences to introductory undergraduates across a wide array of disciplines.

Talk link: `https://youtu.be/A4Tn2w3V_0c`

With the expansion of big data, many research teams across a variety of disciplines are left with more data than they have time to analyze independently. Citizen science (commonly referred to as people-powered research), is an invaluable method that involves crowdsourcing aspects of the data analysis process, enabling research teams to solve problems involving large quantities of data more efficiently while simultaneously taking advantage of the inherently human talent for pattern recognition and anomaly detection (see e.g. Trouille et al. 2019 and the references therein). Zooniverse (`https://www.zooniverse.org/`) is leading the way in providing a robust platform for online citizen science. Since its inception in 2007, the Zooniverse has hosted over 350 projects with over 2 million registered volunteers making over one million classifications across the platform weekly. These projects have led to more than 200 peer reviewed publications to date (`https://www.zooniverse.org/about/publications`).

At a time when citizen science is gaining in prominence across the world, the Zooniverse has become a core part of the research infrastructure landscape. The Zooniverse encourages participation in active research by supporting the general public to contribute to the cleaning, annotating, and processing of scientific data. Zooniverse projects also facilitate direct interaction between citizens and scientists. Raddick et al. (2013) found that the most important motivator for Zooniverse volunteers is the desire to contribute to ongoing scientific research. Through the Zooniverse discussion forums, volunteers discuss objects of interest, generating hypotheses and examining them in the light of new evidence, alongside members of the research team. In addition, each Zooniverse project has a blog and other social media outlets through which research team members share results of the data analysis, publications, and more.

Considering that classifying on Zooniverse projects has a considerably low barrier to entry (volunteers simply need an email address), the Zooniverse team has invested considerable thought and effort to ensure data quality and reliability. Lack of specialist knowledge or misclassification can lead to errors within data produced by citizen scientists (Freitag et al. 2016). Zooniverse's approach to citizen science directly addresses these concerns and has led to an established track record of producing quality data for use by the wider scientific community. By creating consensus results based on numerous classifications, researchers working with Zooniverse have been able engage a disparate crowd of volunteers to produce reliable results (e.g., Lintott et al. 2008, Schwamb et al. 2012, Johnson et al. 2015), leading to discoveries both intentional and serendipitous. Within the field of astronomy in particular, citizen scientists have contributed to the discovery of new exoplanet candidates (Zink et al., 2019, Eisner et al. 2020), identified previously undiscovered protoplanetary disks (Kuchner et al. 2016), and revolutionized astronomers' understanding of galaxy morphologies (Masters et al. 2019). This list is by no means exhaustive, and accounts for just a tiny fraction of the discoveries Zooniverse volunteers take part in on a regular basis.

The Zooniverse is an excellent resource when integrating an authentic research component into college-level general education science courses. By providing these students with insight into what actual scientists do, and how modern data analysis works, citizen science can be used as a tool to contribute to a more scientifically and data literate population of learners. To this end, we have developed four lab-type activities aimed to improve college students' data literacy while emphasizing that citizen scientists make valuable contributions to a variety of scientific disciplines.

Two of these activities based around the topics of extrasolar planets and climate change, incorporated data from the Zooniverse projects Planet Hunters (`www.planethunters.org`) and Floating Forests (`www.floatingforests.org`), respectively. These two activities have been pilot tested with over 3,000 college students enrolled in introductory astronomy and earth science courses. Preliminary results indicated that after completion of these activities, students' confidence with respect to utilizing data-representations (e.g. graphs, charts, and tables) to make evidence-based conclusions increased significantly. Similar results were found for students' beliefs that citizen science is a valuable tool when making scientific contributions, and that they (as non-science majors) can contribute in a meaningful way to real research (Simon et al. 2021 in prep, Rosenthal et al. 2021 in prep). These two activities will be available for public use on the Zooniverse classrooms webpage (`https://classroom.zooniverse.org/#/`) by the Fall of 2021, while we expect the two additional activities developed around the projects Planet Four (`www.planetfour.org`) and Gravity Spy (`www.gravityspy.org`) to be available by the Summer and Fall of 2022, respectively.

For a more extensive list of Zooniverse educational resources, particularly for online classrooms, refer to: `https://blog.zooniverse.org/2020/03/18/zooniverse-remote-online-learning-resources/`

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#RADatHomeIndia a Collaboratory Model of Citizen Science Research

(Big-data is a big-resource for development if citizen science follows a Collaboratory approach)

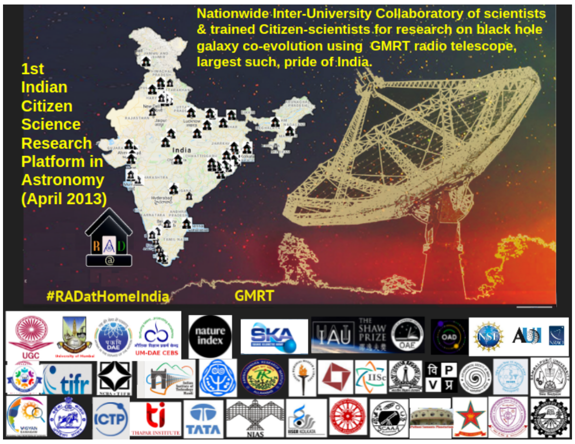
Speaker: Ananda Hota, UGC-faculty, UM-DAE Centre for Excellence in Basic Sciences, RAD@home Astronomy Collaboratory, India

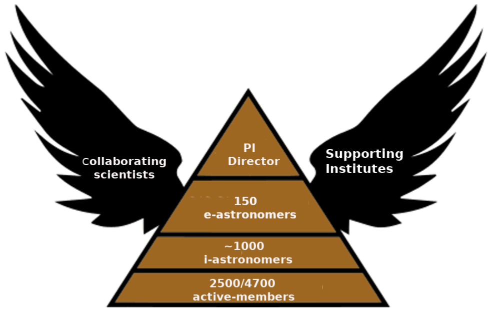
RAD@home (#RADatHomeIndia) is a nationwide, Inter-University Collaboratory of professional astronomers, trained citizen scientists and technical/administrative facilitators. It is the only Indian citizen science research platform in astronomy. Nearly 30 institutes and similar number of professionals have contributed to its growth since 2013. In a "flying pyramid" model, scientists and facilitators are its wings, and large number trained citizen-scientists (e-/i-astronomers) at multiple levels of expertise make the multi-layer pyramid. It has 150 e-astronomers, 1000 i-astronomers, 2500 active learners, 4700 total members. This way citizens achieve GMRT telescope time, co-authorship in papers on galaxy evolution and MS/PhD selections abroad or all round growth.

Talk link: https://youtu.be/VMZzP4BPCsU

RAD@home Astronomy Collaboratory, India (#RADatHomeIndia, https://radathomeindia.org/) is a nation-wide Inter-University Collaboratory of dozen professional astronomers, 150+ e-astronomers (trained citizen-scientists), 1000 i-astronomers & 2500 active learners in a group of astronomy-interested 4700 Indians. Its motto is any BSc/BE/BTech can do research (#ABCDresearch) using the Giant Metrewave Radio Telescope (GMRT) sitting @home anywhere in India free of cost. Though launched as a zero-funded, zero-infrastructure, human-resource network on Facebook and Google on 15th April 2013, the Collaboratory has achieved significant progress since the last eight years. It has grown to be a self-sustainable network of citizen-scientists trained to discover exotic black hole galaxy systems primarily from the low frequency 150 MHz TGSS DR5/ADR1 data taken with the GMRT, the largest such in the world and pride of India. These citizen-scientists not only come from all parts of India, as shown in the map of India, but also from all walks of life, as long as they have entered University-level science and engineering education.

In last eight years, numerous one week-long Citizen Science Research (CSR) training workshops known as "RAD@home Discovery Camps" and one day RAD@home Astronomy Workshops have been organized with the help of nearly 30 institutions all over India, including UM-DAE CEBS (Mumbai) where the Director & Principal Investigator (PI) of the Collaboratory works as an UGC-faculty (University Grant Commission, Ministry of Education, Govt of India). Over 150 students/citizens have been trained in Camps co-organized by this research startup (under UGC-FRP mission). Those Camp-hosting institutions are International Centre for Theoretical Sciences of the Tata Institute of Fundamental Research (ICTS-TIFR, Bangalore), Institute of Physics (IOP, Bhubaneswar), Harischandra Research Institute (HRI, Allahabad), Nehru Planetarium (Delhi),





Vigyan Prasar (Department of Science and Technology (DST), Govt of India). Following Discovery Camps, the CSR continues from home and is facilitated by online e-class-cum-e-research sessions (launched on 14th June 2015) organized by the PI of the Collaboratory. A Camp can accommodate only 10-20 participants. To train and engage even larger community in CSR, One-Day RAD@home Astronomy Workshops (ODRAW) are also organized (as in ICTS, IOP, NISER, IIT (BHU & Mandi), IISER (Kolkata & Berhampur)) and even mini-ODRAWs (IISc & DAE-DST-NCSM Vigyan Samagam (Mumbai, Bengaluru, Kolkata & Delhi)), which can accommodate 50-100 participants who continue to learn from Camp-trained e-astronomers. Purely online/live Workshops are also organized during Covid-19 pandemic (IAU-OAD sponsored programme at Indian Institute of Technology (IIT, mandi), DST (Govt of Rajasthan), Thapar Institute of Engineering & Technology (Patiala)). In these Camps/Workshops/talks nearly 40 Institutes have supported RAD@home and nearly 30 scientists have contributed to the citizen science research training to the students/citizens.

Exotic black hole galaxy systems discovered this way were proposed to the GMRT for deep observation and advanced analyses. These proposals named GOOD-RAC: GMRT Observation of Objects Discovered by RAD@home Astronomy Collaboratory, have been rewarded over 50 hours of observing time, in four different cycles, in this world-class facility after going through standard international review. Several never-seen-before objects/features detecting old/relic magnetised relativistic plasma, emitting preferentially at low radio frequencies of the GMRT (India) than higher radio frequencies of the Very Large Array (USA) telescope, have been detected. Such synchrotron emitting plasma could be due to past ejection of radio jets, millions of light years long and 10-100 millions of years old, from accretion of matter onto super massive black holes, million to billion times the mass of our Sun, located at the centres of massive galaxies. Alternatively, part of the plasma could also originate in the turbulence and shock waves produced during the collision between two clusters of galaxies containing thousands of galaxies each. These cosmic giant particle accelerators, million light years long, accelerate cosmic rays to relativistic speed by Fermi acceleration process and emit synchrotron radiation to be detected by GMRT. We keep our scientific aims well aligned with that of the national and international mega projects. The research results led by the PI have been press-released internationally by NRAO-NSF, NASA-JPL-CalTech, RAS, CFHT, NAOJ-Subaru, NCRA-TIFR etc. and recently has become a representational icon for one of the seven science goals of the Square Kilometre Array (e.g. SKA-brochure explaining galaxy black hole evolution, and SKA-posters in DAE-DST-NCSM Vigyan Samagam). Along with this scientific goal our aim is also to achieve the social constitutional goals of equity, sustainability and inclusivity through empowering the public through the Internet via people-powered citizen science research (CSR). Potential of such a modified CSR collaboration in converting the Big Data problem in to a Big Prospect for a Big Nation has been outlined in the following two publications titled 1. "New results on the exotic galaxy 'Speca' and discovering many more Specas with RAD@home network" (Ananda Hota et al. 2014) & 2. "Tracking Galaxy Evolution Through Low-Frequency Radio Continuum Observations using SKA and Citizen-Science Research using Multi-Wavelength Data" (Ananda Hota, Chiranjib Konar, C S Stalin, Sravani Vaddi et al. 2016). Several citizen-scientists are co-author in these papers. Camp-trained e-astronomers as well as e-class or RAW-trained i-astronomers become co-authors of such journal papers and international presentations. This has been brought to public notice, in the interest of the public, by a News/Press Release in the India Science Wire by the Vigyan Prasar, Department of Science & Technology, Govt of India. RAD@home citizen science research has been highlighted internationally by Nature-Index in an article titled "How to run a successful citizen science project: Keeping participants involved can go a long way". International Astronomical Union (IAU) and Square Kilometre Array, organizations building largest radio telescope on earth, listed citizen science efforts for public benefit, specially to take advantage of it during the pandemic. We welcome individual astronomers for co-authorship in publishing papers and institutions for hosting CSR training workshops (contact: RADatHomeIndia@gmail.com).

GALAXY CRUISE

Speaker: Masayuki Tanaka, National Astronomical Observatory of Japan, Japan

Collaborators: Michitaro Koike, Sei'ichiro Naito, Junco Shibata, Kumiko Usuda-Sato, Hitoshi Yamaoka (National Astronomical Observatory of Japan)

We present an on-going citizen science project, GALAXY CRUISE. GALAXY CRUISE aims to identify interacting galaxies based on imaging data taken with the Subaru Telescope, and it differs from previous citizen science projects in a few key aspects; unprecedented image quality, efficient tutorial based on public experiments, gamified user interface, and two-way communications. We believe that even elementary school students will find GALAXY CRUISE interesting. More than 1.5 million classifications have been collected in 1.5 years after the launch of the project, and interesting results are being unveiled and are shared with the participants. We also discuss future prospects of GALAXY CRUISE, including machine-learning.

Talk link: `https://youtu.be/J-Ru1r7a_eY`

GALAXY CRUISE is a cruise ship sailing across the cosmic ocean. The cruise ship offers an unprecedented view of the Universe with great details of galaxies that have never seen before.

You, as a cruise member, classify galaxies into various categories, which will help professional astronomers to address interesting scientific questions about how galaxies evolve. Unlike previous citizen science projects, GALAXY CRUISE is very interactive and has a lot of gamification aspects; passport stamps, souvenirs, classification ranking, etc. There are also monthly news articles, seasonal promotions, twitter, etc, to keep the cruise members motivated. Over 1.7 million classifications have been made so far and secrets of galaxies are being uncovered.

The Subaru Telescope and Hyper Suprime-Cam

The Subaru 8.2m telescope is located at the summit of Maunakea, Hawaii. It is among the biggest telescopes in the world and has addressed many unresolved issues in astronomy. Hyper Suprime-Cam (HSC) is one of the main instruments at the telescope and a big observing program is being conducted with this instrument. GALAXY CRUISE is based on data from this observing program. Details of the instrument and program can be found at https://hsc.mtk.nao.ac.jp/ssp/.

GALAXY CRUISE

We have launched a citizen science project, GALAXY CRUISE, in February 2020 (Japanese site was launched a few months earlier). It is a cosmic cruise ship sailing across the universe and it provides an unprecedented view of galaxies in the today's Universe.

Scientific motivation: GALAXY CRUISE focuses on morphology of nearby galaxies with an emphasis on interacting galaxies; astronomers know that galaxy-galaxy interactions and mergers are a key phenomenon to drive the galaxy evolution, but its details are not understood very well. The unprecedented images from Subaru make it possible to address this long-standing question.

How to participate: It is easy! Launch your web browser and go to the Galaxy Cruise website (https://galaxycruise.mtk.nao.ac.jp/en/). You can then go over the online tutorial to learn about galaxy shapes. There are three lessons, but they are not very difficult (except maybe for the last one). After the training, you will get a boarding pass to GALAXY CRUISE. Welcome aboard!

Sail around the universe: GALAXY CRUISE has a lot of gamification factors. It takes you to a galaxy and you classify it in an interactive fashion. You can zoom in/out and pan as you like. The universe is split into multiple continents and you will get a stamp on your passport when you leave a continent. You can also collect souvenirs as you go along. We also encourage you to freely explore the universe, discover interesting galaxies and take photos. It is simply fun to sail across the universe!

We will keep you motivated: We issue monthly news articles about various topics about galaxies and citizen science. We also often send messages on twitter. Seasonal promotions are a very popular event and many passengers participate to complete a mission. We also answer any questions you might have during the course of the cruise.

Join GALAXY CRUISE today! We are looking forward to welcoming you on board!

Citizen Science at NASA: Overview and Best Practices

Speaker: Marc J. Kuchner, Citizen Science Officer, Science Mission Directorate, USA

What would you do with help from 10,000 volunteers? Would you scour a complex data set, quickly explore many out-of-the-way places, or simply harness the creativity of that many unique human minds? That is what citizen science is all about: imagining new possibilities, solving hard problems, and at the same time, sharing your love of science far and wide. I will give an overview of NASA's citizen science program, tell the stories of remarkable citizen scientists and citizen science projects, and share best practices gleaned from the NASA community. For more information, take a look at `science.nasa.gov/citizenscience`.

Talk link: `https://youtu.be/xn8BGXQiPGM`

Volunteers from around the world drive NASA's citizen science program, collaborating with scientists on real cutting-edge research. NASA's citizen science projects have come to **dominate** their scientific fields. They have discovered **most** of the known comets, **all** of the known samples of interstellar material, **half** of the ultracool brown dwarfs and **most** of the long period (>2 yr) extrasolar planets from Kepler.

Beyond NASA, the term "citizen science" is applied to a wide range of activities and projects. But at NASA, our policy says: "All NASA citizen science projects shall be designed and implemented to meet the **same rigorous standards as any NASA science** program". As a result of this insistence on rigor, nearly 200 NASA citizen scientists have become named co-authors on scientific papers.

Many of the biggest citizen science discoveries from NASA citizen science have been surprises, recognized by citizen scientists, but unanticipated by the science teams involved: Tabby's star and the "Dipper" star phenomenon (Planet Hunters), the Meyer group comets (Sungrazer Project), the oldest white dwarf with a disk (Backyard Worlds: Planet 9), the Peter Pan disks (Disk Detective), and STEVE, a new kind of auroral phenomenon (Aurorasaurus).

At `science.nasa.gov/citizenscience`, you will find 25 active NASA citizen science projects online, 13 of which are astronomy projects.

NASA Citizen Science as a Tool for Science Education: We are just starting to study this application of citizen science (and note that NASA's educational efforts are now quite limited). But anecdotal evidence is accumulating that we are changing people's hearts and minds and teaching them about science – e.g., students who have changed majors and started science degree programs as a result of their involvement in NASA cit sci. Personal stories of NASA citizen scientists are online at **science.nasa.gov/citizenscience** under People.

NASA citizen science shares the **process of science** with >1.5 million volunteers, including these Shaw University students, who are working on the Floating Forests project.

Several NASA Citizen Science Projects now have classroom materials – see the NASA Citizen Science Resources for Educators document via https://www.dropbox.com/s/b1tuk90vrqsfnxj/NASA_Citizen_Science_Resources_for_Educators.pdf?dl=0.

Here are three best practices collected from our community of NASA citizen science practitioners.

1. **Use citizen science to teach students that in science, everyone's work is checked and double checked.** Scientific work must be reproducible, scientific research must pass peer review, and many citizen science projects have multiple layers of vetting and redundancies in them to ensure data quality. Understanding this aspect of science is a key component of science literacy, and these are special lessons that citizen science experiences can deliver in a uniquely powerful way. Learning these concept helps build trust in science (Weisberg et al. 2021). Help students see the many checks and double checks built into the citizen science projects they use!

2. **Help your students get involved in videocons with scientists!** E.g. Stardust@Home has videocons on the 3rd Thursday of each month. Radio Jove has regular phone calls with volunteers. Planet Patrol and Disk Detective have videocons once per week. Backyard Worlds: Planet 9 has three videocons per week. Participants in these videocons, meet actual scientists, work on advanced projects and observe how scientists work both in teams and in competition. Meeting an actual scientist, even on a videocon, goes a long way toward helping students establish their scientific identities. Ways to get involved are generally described on each project's website—though you may need to read the whole website to find them.

3. **Encourage students to try NASA citizen science on the road to doing a science internship.** When you apply for an internship, working on a NASA citizen science project looks great on your resume because it demonstrates a deep interest in NASA science. For more career and educational opportunities with NASA, see science.nasa.gov/learners/learner-opportunities

Boosting Online Community to Drive Engagement

Speaker: Pamela L. Gay, Planetary Science Institute, USA

Humans are social creatures, and while we all vary in how much we do (and do not!) want to interact, everyone wants a place to belong. With CosmoQuest, we enhance citizen science engagement by making sure those who join know they are welcome and will be supported no matter who they are. This is accomplished by: having a leadership team that is open about their disabilities and differences; using the pronoun "they" until told otherwise; facilitating non-science conversations around topics like LGBTQ+ that impact engagement; providing moderated places where people can hang out; and more. In this workshop, the structure for designing a community will be laid out, and how to emphasize each aspect in your own community will be discussed.

Talk link: https://youtu.be/BhKXaSukTaw

One of our most important roles as Citizen Science project leaders is to show day after day that everyday people can learn and do science; making contributions that help advance our understanding of the universe. To be successful in recruiting people to participate in our programs we have to break down the stereotypes of science being done by isolated geniuses. We would not be able to have citizen science projects if we had not sorted how to do that to some degree. The stories we tell inspire people to join our projects. We see in our data the folks who want to contribute, and who will click and observe for years, content to know they are making science possible. We also find there are community leaders, engaging in both science and in facilitating conversations and communications in our forums. With these core groups, we end up with groups that in many ways reflect professional science communities. But can we do better?

Professionally, astronomy is male-dominated, white-dominated, and we need safe places and support groups for members of the LGBTQ community and people of faith. If we do our job right, our communities will not reflect our profession, but be a better version of the diverse society we live in. This is not to say we can be a true reflection of society - my programs are not suitable for the blind, and they require people to have computers, free time, and the ability to learn certain needed tasks. These are limits.

This brings us lesson 1: Decide who you want to be as a community. At CosmoQuest we start by targeting the science adjacent: sci fi lovers and podcast listeners. From there, we say "we will tolerate no hate. This is a place where people are accepted without regard to their color, culture, religion or lack of religion, their education level, their wealth, or their caste. We do not care who you love, but only that you find love in this world. We believe that everyone can do great things, and we welcome everyone to be part of us doing great things." When we started our program, we drew in our audience from the Astronomy Cast podcast audience, and we started out primarily male, white, educated, and affluent. This was not our goal, so we have worked to change as we grow. This required us to both listen on platforms like Twitter when people talk about why they do not feel welcome in the sciences, and learn. It also requires us to ask the people we do have who are not the generic affluent white male science lover why they have joined us, and why they stay. This is an iterative process; people and society are constantly evolving, and it is a process we can never call good enough.

When you decide who you want to be, you should strive to reflect that from top to bottom. This meant asking, 1) what is necessary to create a work environment that is welcoming and supportive of a diverse staff, 2) are we communicating in ways that are as inclusive as possible, and 3) does our community provide support to people such that we are providing a place that provides equity rather than just equality.

To facilitate a diverse staff, we looked to Bryan Gaensler's efforts at the University of Sydney and at Dunlap Institute. All paid positions have allowed part-time and flexible hours. We make it clear that we will schedule meetings around family obligations, and make it a goal that everyone is cross-trained so folks can take time off without work piling up behind them. We also approach our volunteers from a position of trust; assuming people who want to help might make mistakes but can be trusted just as much as our staff, and may have more experience or expertise than we could afford to hire on academic budgets. Today, our core team is made of majority women, and quite by accident, we have landed in a place where we are all some combination of disabled, queer, and/or people of faith; we are the people who are not majority in science, and we are the leaders of a community who seeks to reflect society instead of science. No group starts as actually diverse. It is a process. Lesson 2: Find the kinds of people you want to see in your community who are not already there, listen to them and learn what they want, need, and dislike. Then change what you need to change.

Creating a place of diversity has required the entire team struggling together to find ways to present ourselves that leave spaces for everyone to feel included in our messaging. This takes many forms. For instance: we default to the pronouns they/them until we are told to use something else. We work to provide transcripts of all of our recordings, and to make content available in ways that can be accessed with screen readers and on multiple devices. We also make efforts to admit our own differences, struggles, and failings so people see role models, and if not role models, at least space for their differences to exist alongside our differences. This care is carried all the way through to how we word surveys. When we ask, "What is your gender?" it is not multi-choice. After talking through how people want these questions to appear, we now give people a blank space to answer. This makes data analysis harder, but leaves space for humans to be true to themselves.

In a recent marketing survey, we found that the majority of the community is still male, at about the 70% level, and uncomfortably white. That said, more people identified as having a disability than is typical of the US population, LGBTQ roughly tracks with the population, and our community includes many self-identifying conservative religious folks who co-exist in a community with no clear majority between atheists, agnostics, and people of faith. This was a non-scientific study used to understand how to improve programs. We are seeking funding for more in-depth research. Of particular interest, we want to explore how the digital divide affects engagement by minorities, and how the demands of household and children - the so-called second-shift - impact the ability of women to participate in citizen science and other volunteer activities.

Lesson 3: You need to set down community guidelines that are enforced with room for forgiveness and honest mistakes. Part of creating rules is asking "What is required to make the people we want to welcome feel comfortable? We have forbidden references to weapons or violence, even Marvin the Martian. Sometimes this takes forms I never quite imagined. Recognizing that people are more than the science they do, our discussion server has channels to share photos of nature and animals, and all spiders and snakes are hidden behind Spoiler Tags. It is a small thing, but it matters. We do what we can to create a community focused on helping and contributing. This includes people live streaming their citizen science efforts and sharing their pain and triumph, and it has matured in these Covid times into people supporting each other in voice chats, and when folks need a break, we even created a place to play games, tell stories, and just be humans.

We have adopted a spirit of aggressive acceptance and compassion and are becoming who we want to be. I hope our lessons will help you build the long-lasting, healthy and growing community that you want to see.

How Citizen Scientists are Monitoring Global Meteor Shower Activity with Machine Learning Open Source Research

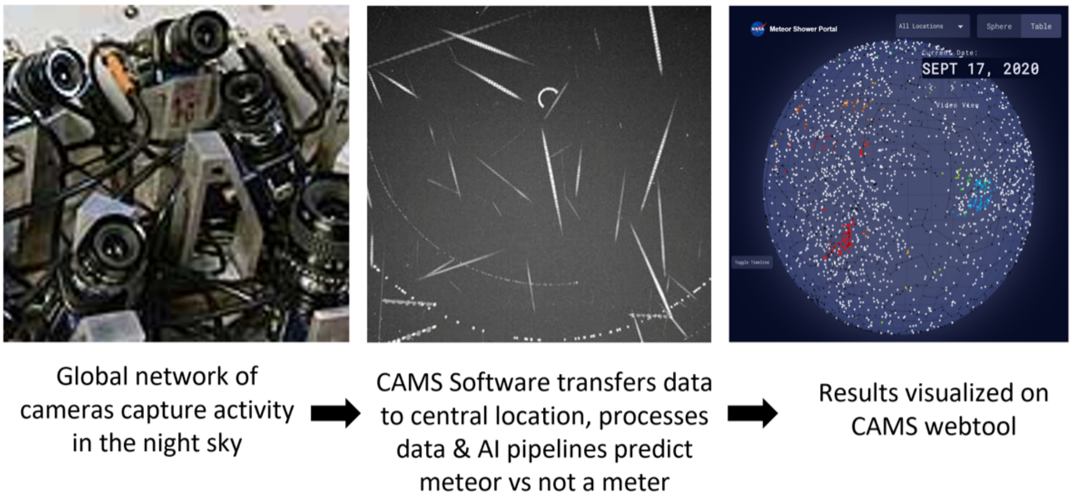
Presenter: Siddha Ganju, Frontier Development Lab, SpaceML, Nvidia Corporation, USA

Citizen scientists have automated the Cameras for Allsky Meteor Surveillance (CAMS) data network, so data is automatically downloaded from the cameras, prepped for triangulation, and analyzed. Additionally, an ML algorithm replicates the scientists thought process to sift through the video captured each night to identify meteor showers with results published on the NASA CAMS Meteor Shower Portal. The open source portal not only aids in effective communication of ideas and results to a diverse audience but is a useful interactive educational tool used to explore meteor shower activity from the previous night globally and encourages citizen scientists to develop an interest in space science. Learn how to reuse the open source code for your datasets and explore meteor showers!

Poster link: https://youtu.be/qbppM0c4dHs

While many of us in astronomy are domain experts, we could utilize the talent and skills of people outside the domain, and that is where citizen science can help. With proper engagement and mentorship, citizen scientists (ranging from high school to university students, all the way to tech industry veterans) can be guided to start contributing innovations to astronomy, spearheading research into new uncharted domains, ultimately publishing research in journals and top conferences.

CAMS or Camera for All-Sky Meteor Surveillance project (https://www.seti.org/cams), which started with just a single camera trying to map the night skies above California, has now grown to 600+ cameras today, spanning citizen scientist-run observatories all over the globe such that we have eyes on the skies worldwide 24x7. Peter Jenniskens (https://www.seti.org/our-scientists/peter-jenniskens) who founded CAMS would travel daily to the Lick Observatory, take the hard drive, drive back to the SETI Institute and replay the captured data, sitting in long moments of uneventful darkness waiting for that momentary streak of light to verify if it was a meteor or not a meteor. Teams of citizen scientists have built the (1) CAMS software that transfers data saving valuable time but also an incredible amount of carbon emissions, (2) trained an AI model to replicate the scientists thought process to distinguish between meteors and other objects in the night sky, and (3) build a user-centered visualization portal that displays night activity from all over the world within your browser.



The figure shows the CAMS pipeline build by a team of citizen scientists.

As of 2021, CAMS is a mature TRL-9 deployed machine learning project for planetary defense and has been one of the first machine learning-enabled NASA-funded projects that includes pro bono contributions from citizen scientists. CAMS has run multiple Facebook, YouTube Live events with 10k+ views. Recently, a team of student citizen scientists were also able to organize a fundraiser, raising 30,000 USD to establish camera stations in India, closing the blind gap which existed over the North-Eastern Hemisphere.

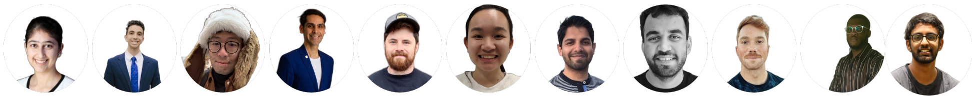
SpaceML: How to run a citizen science team/Learnings from running the Citizen Science team: There are few organizations in the world like NASA, where the opportunity to work can have a huge positive impact on the planet. However, opportunities are very selective, often available to researchers with advanced educational backgrounds, with the most common starting positions being Postdoctoral positions. And while the funnel of students in advanced STEM fields is already low, it is even lower for women and people of color.

SpaceML helps connect aspiring change-makers with the opportunity to make an outsized impact. It does that by inspiring them through talks, training them, opening opportunities to conduct research in a state of the art field, guiding them through generating publications and releasing free open-sourcing tools, and then giving them the stage to showcase their work in front of NASA Scientists, significantly accelerate the speed of usable research for NASA and its adoption by scientists. And it does it in an inclusive manner, irrespective of academic background. With 50+ contributors now, starting from summer 2020, the majority of the students have a high school / undergraduate background. With the students scoring an open offer for future internships. And even two English teachers who were motivated by climate change, who went through a career transition into data science, with one having landed in a full-time technical role. And more importantly, with stories of relatable young changemakers, more people will follow onto using their talents for social good.

The north star for the program is not research but readily usable, deployed research, a shortcoming in the common academic research process. Most free tools released in this program do not require the user to know computer programming or pre-requisite knowledge of artificial intelligence, all it requires is one line to get them running. This further reduces barriers to entry and enables researchers across all disciplines to benefit from the project.

The program facilitator provides customized learning resources to each candidate to upskill them in a fast yet approachable manner. Few weeks in, they are paired with their primary mentor who will closely guide them through the rest of the program. Mentors meet with their mentees every week to discuss progress on their project, next steps and longer term goals. As the project reaches a certain level of maturity the candidates present their work to a panel of NASA scientists and stakeholders. This step serves as a useful checkpoint to ensure that the project is going in the right direction and that it is readily deployable for real-world scenarios. Contributors are held accountable through a set of key objective metrics. Through this process of delivering short yet impactful demos, the candidates learn valuable skills in public speaking and presentations. The candidates are also provided guidance on scientific communication for research publications at prestigious conferences.

SpaceML is unique because there exists no other distributed open-source program that upskills contributors from a variety of backgrounds (technical and non-technical), ultimately helping them deploy code for high public value areas like planetary defense, climate change in a short span of time.



Zooniverse and IASC: Citizen Science at the Service of the Popularization of Astronomy

Presenter: Felipe Sérvulo Maciel Costa, ECIT Melquíades Vilar, Brazil

In times of remote education, astronomy education has also had to adapt. Today, there are citizen science projects that provide tools and resources to support astronomy education remotely, such as the Supernova Hunters and Planet Hunter Tess projects on the Zooniverse platform, as well as the International Astronomy Search Collaboration, an asteroid hunting project. In addition to contributing to astronomy education, such projects also allow citizen scientists and amateur astronomers to contribute to new discoveries of planets, supernovae, stars, and asteroids not yet discovered by the algorithms that scour the cosmos through large telescopes. Such initiatives also have the potential to contribute to the popularization of the field of astronomy and general interest in STEM.

Poster link: https://youtu.be/i6WhN-fYSEc

Started in the mid-1900s and popularized in the last 20 years, citizen science is the kind of science that involves the participation of volunteers who actively contribute in various areas of research. In the field of astronomy, in addition to seeking a greater participation of amateur astronomers and astronomy enthusiasts in scientific research, there is a parallel objective of providing greater dissemination and increased general interest in the areas of STEM (Science, Technology, Engineering and Mathematics), more specifically, in the field of astronomy (which can be called citizen astronomy).

Currently, there are initiatives such as Zooniverse (www.zooniverse.org), a virtual platform that hosts the largest citizen science projects on the internet and is headquartered at Oxford University and at the Adler Planetarium. Zooniverse's projects span several areas of knowledge, including astronomy, ecology, cell biology, humanities and climate science. Some examples, in the field of astronomy, stand out the Planet Hunter Tess (project that identifies exoplanets through starlight curves recorded by the TESS telescope), the Supernova Hunters (project that searches for supernovas through images from the PanStarrs Telescope), Cosmological Jellyfish (initiative that searches for exotic galaxies), and the recent Active Asteroides project, which searches for asteroids with characteristics of a comet. Another important citizen astronomy project is the International Astronomical Search Collaboration (IASC - http://iasc.cosmosearch.org/), one of NASA's citizen science projects that provides high-quality astronomical data to citizen scientists around the world through search campaigns by major belt asteroids (MBAs).

In recent years, there has been a considerable increase in the number of people joining citizen science initiatives aimed at astronomy (citizen astronomy) around the world. Participation includes astronomy clubs, schools, science dissemination projects, universities or even amateur astronomers or astronomy enthusiasts. The present work evidenced the participation and discoveries of the Mysteries of the Universe Project, from Taperoá, Paraíba, Brazil, and the Melquíades Vilar School, in the projects of citizen science of asteroid search (IASC/NASA/MTCI) as well as in the search for supernovae (Supernova Hunters/Zooniverse) between July and September 2021. Citizen astronomy is a two-way street: more people contributing to citizen science projects helps to improve and refine astronomy research, improve the algorithms. and produce more data, at the same time, these people learn. Without leaving home, with the help of the internet, teachers, students, astronomy enthusiasts and astronomy club members have the opportunity to contribute to cutting-edge professional science in astronomy and participate in important discoveries. In addition, citizen science projects aimed at astronomy promote the growing participation of people in science, multiplying the number of enthusiasts (including children), and fostering interest in astronomy.

Solar Eclipse 2019: Citizen Science Initiative to Investigate GPS Signals in Chile

Presenter: Carla Hernández, Center for Interdisciplinary Research in Astrophysics and Space Exploration (CIRAS) Physics Department, Universidad de Santiago de Chile, Chile

Collaborators: Sebastián Pérez, Roberto Bernal, Marina Stepanova, Cristóbal Espinoza and Miguel Pino, CIRAS, Physics Department, Universidad de Santiago de Chile

The solar eclipse in Chile 2019, was a perfect opportunity to invite the public to join a scientific investigation through a citizen science initiative. The aim was to gather data that would help us understand how changes in the illumination pattern affect our planet's ionosphere. Shadowing by the Moon is expected to produce deviations in the Global Positioning System (GPS) accuracy. Our initiative, named "Hago Ciencia", invited people to collect GPS data with their smartphones before, during, and after the eclipse. Participated approximately 5,000 people, providing more than 280,000 geolocation. We found evidence that the positioning accuracy worsened by several decades of meters during the passage of the Moon's shadow when compared to before and after the time of totality.

Poster link: https://youtu.be/pTe5cNVXJGM

The solar eclipse that happened on July 2, 2019 was visible throughout continental and insular Chile, with magnitude 1.0459; Range -0.6466; and a maximum duration of 273 seconds (4 min. 33 sec.).

On this occasion, we developed a citizen science initiative called "Hago Ciencia" (translated as "I do science") in order to encourage the participation of people throughout the country. The initiative was aimed at studying how the main ionosphere is affected by reduced sunlight for a short time interval, by detecting changes in artificial geolocation systems. Studies in previous eclipses of the Sun have reported weakening of the ionosphere and effects on the transmission of radio waves (Cervera and T. J. Harris, 2014).

During a solar eclipse, when the Moon blocks the solar radiation completely over some area of the ionosphere, we expect changes in the density of free electrons in that gas column. A 60% decrease of the electron density in the F1 region was observed during the maximum of a total solar eclipse (Ding et al., 2010; Coster, A. et al., 2017).

Citizens had to enter the designated website through their mobile phone, and accept access to geolocation data. In the instructions, users were suggested to connect several days before, at approximately the same time of the eclipse (16:30 CLT) from the same place of registration. The

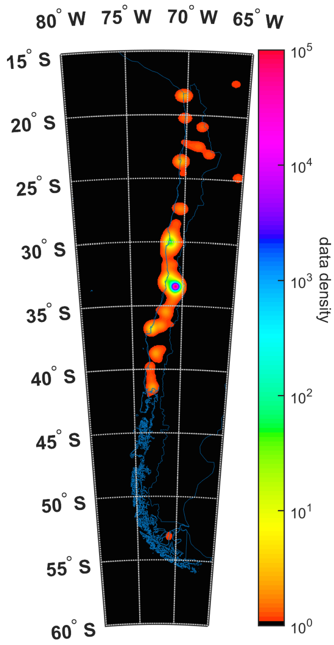


Figure 1: Density data distribution/latitude.

initiative involved 4,809 people who contributed to the registry of 284,610 geolocation data (Figure 1). Registration was carried out from different parts of the country, both in continental and insular territory.

We found evidence that the positioning accuracy worsened by several decades of meters during the passage of the Moon's shadow (Figure 2). The results obtained suggest that the GPS embedded into the cell-phones are able to detect the changes of TEC. This finding was possible thanks to the active participation of citizens in the data collection process. High citizen participation during the eclipse and the large amount of data collected in this initiative confirms the community's interest in scientific research.

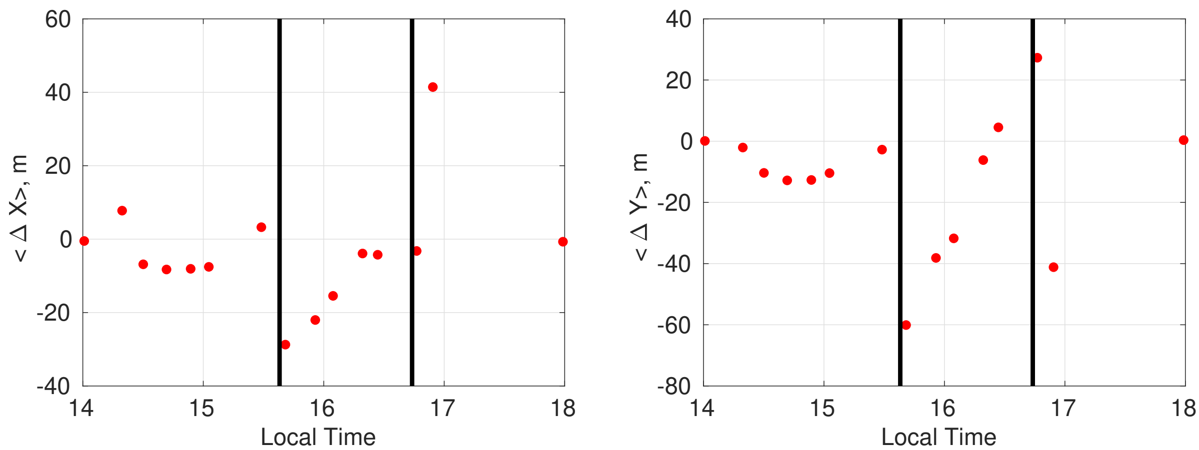


Figure 2: Averaged differences in meters between the apparent and real locations of cell-phones in latitude (Y) and longitude (X).

GWitchHunters - The Citizens for the Improvement of Gravitational Wave Detectors

Presenter: Francesco Di Renzo, on behalf of REINFORCE-WP3, University of Pisa and INFN section of Pisa, Italy

Gravitational wave detectors are very sophisticated instruments devoted to the formidable task of measuring space-time deformations as small as a thousandth the size of the atomic nucleus, such as those produced by astrophysical phenomena like coalescence of compact stars or the Big Bang itself. This citizen science project aims at demystifying the detectors functioning and the work of the scientists to improve them. We present their data in the form of images and sounds, and we ask the citizens to identify relations between them or peculiar patterns in images and sounds. All of this is presented with the interface of the Zooniverse platform as a game for the citizens, which, playing with simple tasks, can give a significant contribution to better understand the detectors and improve them.

Poster link: https://youtu.be/KmJgBJKQuzg

GWitchHunters, from the blending of the Gravitational Wave acronym (GW) and glitch hunters, is a citizen science demonstrator developed within the REINFORCE (Research Infrastructures FOR citizens in Europe) Research & Innovation Project, with the support of European Union's Horizon 2020 SWAFS "Science with and for Society" work program. Its objective is to engage and support citizens to cooperate with scientists in the field of gravitational wave research. In particular, this project aims at delivering a deeper, but easily accessible, knowledge of the physics behind GW detectors and how these can be improved to achieve better sensitivity for the experimental study of the Universe.

The first step in the development of the project has been to present the data recorded by GW detectors in a format that enhanced the physical properties of interest and that these were easily recognizable by the general public, without any specific expertise in signal processing. Our focus has been in particular on transient signals, such as those expected from the coalescence of compact binary stars, like the celebrated first detection event GW150914[1], or other short excesses of energy of environmental or instrumental origin, colloquially referred to as *glitches*. To represent them we make use of specific transformations that normalize the data with respect to the energy of its stationary and Gaussian part (*whitening transform*), and we visualize them by means of *spectrograms*, heat maps that show the evolution of their energy with time and frequency.

In order to make concepts like energy and frequency more friendly to unexpert participants,

[1]Abbott, B.P. et al., "Observation of Gravitational Waves from a Binary Black Hole Merger," Phys. Rev. Lett., vol. 116, no. 6, p. 061102, 2016.

like young kids, and provide a multisensorial view of this data, useful for people with vision impairment, we have developed a new *sonorization* strategy to convert the spectrogram images into sounds. We have done that associating to every frequency interval of these images the corresponding note of the C-major scale of Occidental music, that is, the white keys of a piano keyboard. Then, the energy in each band is associated with the intensity one plays the corresponding note. This strategy encourages practical demonstrations of signals examples at outreach events or in schools, making use of common musical instruments.

From these images and sounds, we can recognize the peculiar shapes and tones associated with the coalescence of compact binary stars and those from signals of terrestrial origin, which we would like to get rid of in the search for astrophysical signals. Most importantly, we are then able to distinguish them, and this is one of the tasks that the participants in this project are asked to accomplish.

Moreover, besides the data channel that records the gravitational wave *strain*, our detectors constantly monitor the status of their instruments and environment with dedicated data acquisition channels. If we observe the coincident presence of an excess of energy in the main channel and in one of the latter, with a similar image shape or sound, then this provides evidence for a terrestrial (i.e. instrumental or environmental) origin for that, and also gives researchers information on where in the detector this noise has spawned from. This is very important for the identification of the various noise sources and, getting rid of them, the improvement of the detector sensitivities. This is also one of the tasks that citizens are asked to complete in the GWitchHunters.

We have delivered this project via the Zooniverse web platform, which includes a nice looking interface for visualizing the data and performing the previous tasks, and also plenty of additional resources and discussion boards about the science of gravitational wave detectors and how to get in touch with researchers in the field.

Discussion summary

The two informative citizen science sessions were followed by very lively discussions. Overall there was a consensus that not only does citizen science prove to be a very useful tool for outreach but it also helps with introducing research activities and methods. It is essential to find the right balance between outreach and authentic research, while designing citizen science projects. To make sure that the project is rigorous and productive scientifically, it is beneficial to include scientists in the team, to define a clearly stated science question that is accessible for everyone and to have the data quantity and quality as needed to answer the question. It is also important to strive towards a more equal, diverse and inclusive community, which takes a lot of work and dedication.

To grow the community further, a few ideas of promoting citizen science projects were discussed. Ananda Hota mentioned the importance of highlighting the outreach aspect of citizen science initiatives, especially in order to acquire government funding and recognition. Masayuki Tanaka and Pamela Gay encouraged using social media to help spread the word, e.g. facebook groups, promotions via National TV stations as done in Japan for GalaxyCruise, and different live streaming platforms like discord, twitch, YouTube live, etc.

There was a discussion about including citizen science projects into the K-12 curriculum. Molly Simon suggested that many of the activities developed for college students can be used in high school classrooms and that the Zooniverse projects on the website are accessible to most ages, starting with middle school (https://blog.zooniverse.org/2020/03/18/zooniverse-remote-online-learning-resources/). Marc Kuchner pointed out that there are some challenges for classroom projects in the USA since the next-generation science standard curriculum does not have a lot of flexibility for adding these kinds of activities. However, several NASA projects have been successfully incorporated for high-school students in India and Brazil. Pamela Gay stressed on the importance of being respectful and giving due credits to all those involved at different levels of the initiative, especially among minority students (see also https://arxiv.org/abs/1907.13061). Pamela Gay mentioned that several different citizen science projects exists, which also work in areas lacking the access to technology, such as observational work that uses unaided eye where the data can be reported through the phone (e.g. monitoring novas for AAVSO, https://scistarter.org/).

Marc Kuchner shared a funding opportunity called the NASA Citizen Science Seed Funding Program (https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId=%7BA08B277F-1BFE-4663-3E6F-C178EBA87C8C%7D&path=open) for educators or researchers who want to propose new projects in Astrophysics, planetary science, biological and physical sciences, and Helio physics. Molly Simon also shared that the publicly available project builder tool (https://www.zooniverse.org/lab) on the Zooniverse platform can be used to build a Zooniverse project and get help from 2 million+ volunteers around the world to classify the data.

Although involving machine learning techniques in citizen science initiatives seems like the way forward, Marc Kuchner emphasized that citizen scientists will always have a feature that machines do not have, and that is curiosity. The more we can inspire people from all kinds of backgrounds, the more science we will do!

Daytime Astronomy

Session organiser: Markus Nielbock, Office of Astronomy for Education/Max Planck Institute for Astronomy, Germany

Session overview

Daytime astronomy challenges our expectations of what astronomy entails. Our first associations revolve around the night sky, rich in fascinating objects like the Moon, planets, stars, constellations, nebulae, globular clusters, and galaxies. However, there are many exciting concepts connected to celestial objects that everybody can witness even in daylight. Firstly, there is the Sun, but we can also find the Moon and certain bright planets during the day or in the twilight of dusk and dawn.

Daytime astronomy also helps us to connect with our cultural heritage. Seasons, timekeeping, and the calendar are closely related to observing the apparent annual motion of the Sun and the Moon.

One major advantage of daytime astronomy activities is they happen during regular school hours. As such, they potentially reach many children and enrich their teaching with easily accessible hands-on exercises. Therefore, daytime astronomy is exceptionally well suited to teach basic astronomical concepts with few barriers concerning availability during the day and avoiding possible safety issues at night.

This session highlights a series of six talks and three posters that present various activities and best practices to teach fundamental phenomena of the Sun-Moon-Earth system. They include examples for diurnal and annual solar motions, activities to measure the size of the Earth, as well as tips for observing solar eclipses safely.

Sun, Shadow and Sky: Glimpses of "Daytime Astronomy" Activities

Speaker: Venkateswaran Thathamangalam Viswanathan, Vigyan Prasar, New Delhi, India

Time reckoning and seasons are linked to the apparent position of the Sun in the sky. Outdoor project work helps to determine the cardinal directions, local (astronomical) noon & standard clock time, yearly noon shadow changes, rough time reckoning and seasonal day length changes. Few activities can be completed during the day, and some will require measurements and observations on different days of the year. The learners observe and note the key aspects, contextualise them, undergo a cognitive apprenticeship, help analyse and interpret information, and learn to work in groups. Observing and interpreting the gnomon's shadow and the project encourages young people to participate in knowledge generation.

Talk link: `https://youtu.be/IMXicn-eFJ0`

Astronomy evokes the image of the starry sky, Moon looming large, and the planets meandering in the background of the celestial sphere. One may even consider that "daytime" and "astronomy" to be opposite of each other and that "daytime astronomy" is an oxymoron. Yet, in the history of human civilisation, the dawn of astronomy was marked by the observations of the Sun in the sky and the shadows it casts. The sun provided the cue for computing the time elapsed since the sunrise (or the time remaining before dusk falls) and longer time-division such as seasons and years. Daytime astronomy (DTA) activities attempt to recapitulate these for education, popularisation, and outreach efforts.

What can we observe in the daytime? We will illustrate some of the activities that can be carried out in the daytime by observing the motion of the sun and the shadows it creates.

<u>Sun does not rise in the east:</u> A simple activity would clarify that the Sun does not "rise" at the same point on the eastern horizon. Choose a spot on your terrace with an unhindered view towards the east, and mark it. You will have to stand on that spot many times during this exploration, making the mark durable. Watch the sunrise as it goes above the parapet wall. Ask your collaborator to place a stone on the parapet wall such that the stone and the rising Sun are in a straight line. Come back to the same spot, say after every fifteen days, for say two to three months, and at each time place a new stone that marks the sunrise point. Mark each stone with the date and time at which you made the observation. We can quickly find that successive sunrise points are moving towards the southeast for the six months, and towards the northeast,

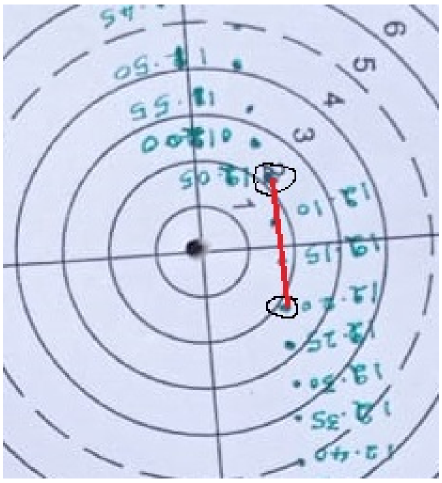


Figure 1: When you join two points on the same circle, we get the west-east line.

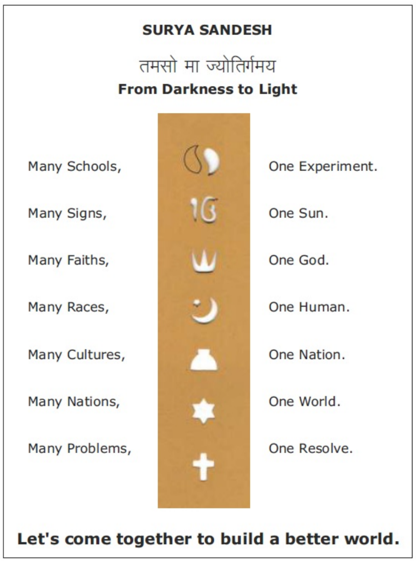


Figure 2: The holes perforated in the shape of various faith symbols project distinct images when held closer and all become circles when the distance to the screen is increased.

in the next six months. The southeast position is closer to December 21 (winter solstice), and the northernmost place is closer to June 21 (summer solstice). "Sun rises in the east": as we understand it, is not that correct. With careful observations (and nudging from the facilitator), we can find that the sunrise point is very close to the actual east on two days in a year called the equinoxes.

Your shadow your clock: An ancient verse in Tamil tells us how to compute the time during daytime from measuring your shadow with your feet measure. Choose a rock or the edge of the pavement (or any fixed object) as the mark. Adjust your position in such a way that the shadow of the tip of your head kisses its edge. Now measure the length of your shadow, with your feet, by slowly tiptoeing towards the stone/pavement.

In the old days in the southern part of India, they used a time division called "Nazhigai", which is equivalent to 24 minutes. From sunrise to sunset, there were 30 Nazhigai. If your shadow length is 98 feet measure (by your feet! This is important, remember), then from sunrise, it is not more than one Nazhigai (or 24 minutes). Alternatively, if it is afternoon and the shadow is pointing towards the east, then in 24 minutes, the sunset will take place. If the shadow length is 45 feet measure, then it is two Nazhigai (48 minutes). The table is given a pair. The first number is the shadow length in feet, and the second number is the time in Nazhigai since sunrise or the time remaining for sunset. (98:1), (45:2), (28:3), (19:4), (14:5), (10.5:6), (8:7), (6:8), (4.5:9), (3.5:10), (2.5:11), (1.75:12), (1:13), (0.5:14), (0:15). This works roughly for southern India; I am not sure this would work for your place as it is. Why not try measuring the shadow lengths? Prepare a table for your area.

When is "midday"?: The clock time 12:00 is not when the Sun crosses the meridian line at your place. Place a vertical pole. Draw concentric circles on paper (as shown in Figure 1) and place a vertical rod (pencil) at the centre. Note the shadow point of the tip of the pole every five minutes. When two points fall on the same circle, add the clock time of these two points and divide by two; we get the astronomical noon. In Figure 1, the points corresponding to 12:05 and 12:20 are on the second circle. Add them 12:05+12:20 and divide them by two. We get 12:12; that is the midday/astronomical noon at the location where this observation was made.

Cardinal directions: Draw a line connecting the two points falling on the circle (Figure 1); that is, the east-west line. Now draw a perpendicular to that line passing through the centre, we get the north-south line.

Shadow flips: If you watch the pole's shadow during the astronomical noon every day, we will observe an interesting phenomenon. In Chennai, from August 18 to April 24, the pole's shadow would be towards the southern direction. On April 25, the direction of the shadow would be west-east. At astronomical noon, there will be no shadow – Zero Shadow Day! However, on April 26, the shadow would be pointing north! It would point towards the north until August 16. On August 17, once again, the shadow would be west-east and at noon, no shadow. Once again, Zero Shadow Day. From the next day, August 18, the shadow of the vertical pole flips to the southern direction.

Message from the Sun: The Surya Sandesh Sun card, developed by Dr Vivek Monterio (Figure 2), shows how science activities make us reflect on our understanding of the world and produce a much better mutual understanding amongst us. In these dark times of hate, sectarian violence, demonisation of people belonging to other "faiths" and belief systems, good science education must also cultivate what in India we call as "scientific temper"; an attitude that is steeped in temperament for reform, humanism and spirit of enquiry. "Surya Sandesh" means "message from Sun". When you hold the card, with perforations marking various faith symbols close to the ground, in the shadow cast, each symbol appears distinct. When we slowly raise the card towards the Sun as high as possible, initially, all faith symbols become the same; circles of light. When we go even higher, the circles touch and merge into each other, symbolising our essential oneness as human beings, as citizens of planet Earth. We are One under the Sun.

Only a few illustrative activities are listed above. Fun and learning are possible with many more such activities using low cost/no-cost contraptions. One can make a sundial, measure the altitude of the Sun at midday to trace the path in the sky, find your latitude and many more. Even in the resource-poor scenario, these are eminently feasible. For example, Navnirmithi, a Mumbai based science education group, had developed "Ball-mirror assembly" solar projection. With this, every school around the world can have a solar observatory for exploration and learning[1]. Roleplay[2] is also an effective tool. The Public Outreach Committee of the Astronomical Society of India[3] is also developing apps/activities. You can also watch DTA videos by Vigyan Prasar[4].

[1] see for the construction and uses of the ball-mirror assembly: https://www.vidyaonline.org/dl/sun-earth-games.pdf

[2] https://www.arvindguptatoys.com/arvindgupta/role-play-eng.pdf

[3] https://astron-soc.in/outreach/activities/zero-shadow-day/

[4] https://www.youtube.com/watch?v=YUYA7NWocO8&t=4s and https://www.youtube.com/watch?v=9FHT6R-Hm4Y&t=5s

Where Are We? How Do We Move?

Speaker: Edgardo Quintana, Colegio San Francisco Javier, Puerto Montt, Chile

If somebody asks me "What Everyone Should Know About Astronomy Education", it would be concepts like "Where Are We?" and "How Do We Move?". I think that this information and associated activities and methods, give us a perspective about who we are. The talk shows the movements of the Earth in the southern hemisphere, the path of the Sun during the day, the connection with the southern celestial pole, and the different experiences with activities that complement this journey.

Talk link: `https://youtu.be/3wiFEWsZpdU`

What everybody should know about Astronomy Education: I think we need to add an approach that connects astronomy with the humans; something like what is generated when you find yourself contemplating a starry night, but from an education point of view; an assimilation of the context in which we situate ourselves as beings. I think that this "assimilation" of astronomical knowledge is important and contextualizes our existence. By educating about astronomy, we can connect life with what science tells us about what the Universe is like. We ask ourselves again "what are we" "how does life originate".

And well how do we achieve this?: My opinion on what we should know about astronomy education is based first, as a start, on explaining, "where we are" and "how we move" in space.

Where are we?: "We are in the solar system, within a spiral galaxy called the Milky Way, at a distance of 28,000 light years from the center, where there is a supermassive black hole. At the same time this galaxy is immersed in groups of galaxies."

When thinking of our Solar System we can observe the Moon and the Sun during the day. The Sun is eight light minutes and the Moon is one light second away. From our observatory, it is also possible to photograph them. The following activities are possible:

Concerning the craters of the Moon, students can point at those visible from our location.

Students can recreate their bound rotation through an activity in which they revolve around each other while facing each other and wearing masks of the Sun and the Moon. They show why only one side of the Moon is visible.

Students can also visualize sunspots and their movement through time while observing the rotation of the Sun with the help of information from the SOHO satellite page.

Students can make a solar system scale model. A tactile model would also allow for activities including blind people.

To comprehend sizes, students can compare the diameters of the Moon, the Earth, and the Sun with images that are to scale.

To understand eclipses, students can take pictures, work with a lunarium and a lunar calendar.

While applicable to any object orbiting a massive object, such as Jupiter, the Sun, the Moon, etc., it is possible to carry out a mapping of the distance scaling of Galactic objects. Here you can take advantage of Kepler's Third Law and the concept of uniform circular motion to extend the laws valid in the Solar System to also calculate the mass of the galactic central black hole with the star S2, knowing the period and the distance at which the star is from the center. It joins with trigonometry, in Chile for 11th graders.

I find that there is information that is very important if we want to understand where we are. This is related to the location of the star closest to us "Proxima Centauri" at 4.3 light years. This star is not observable during the day, but it is possible to refer to it when we see how the Earth revolves around the southern celestial pole. In this part, it is possible to explain what one light year is and calculate that distance in kilometers or compare it to the Earth-Sun distance.

Students can create a velocity-time graph assuming that we want to travel to that star. It can refer to the highest speeds that human beings have been able to reach when traveling through space. This touches the concept of uniform rectilinear motion. In passing, we can connect the activity with the study of exoplanets Proxima Centauri b and c.

Finally, students can realize that at 70,000 km/h it is possible to reach that star from Earth in 100,000 years. Consequently, we are very far from other objects. If there is no nearby life in the Solar System, we would be even more alone. That tells us that our planet behaves like an island in the middle of a huge ocean.

How do we move?: "The Earth rotates and is tilted with respect to the ecliptic. We move on a nearly circular orbit at a speed of approximately 100,000 km/h around the Sun. The solar system also moves around the center of the Galaxy".

The rotation of the Earth is possible to appreciate with the apparent movement of the Sun through the day. In our city, Puerto Montt, it is possible to see the Sun rise in the morning from the mountain range towards the sea, passing over Lake Llanquihue. It is very important to have a reference since in this way we can compare different sky positions. From here, we see the volcanoes Osorno, Calbuco and Puntagudo. With the months changing, we can observe the apparent path of the Sun. In winter, we see the Sun pass at a low altitude and in summer at noon it is possible to appreciate it near zenith.

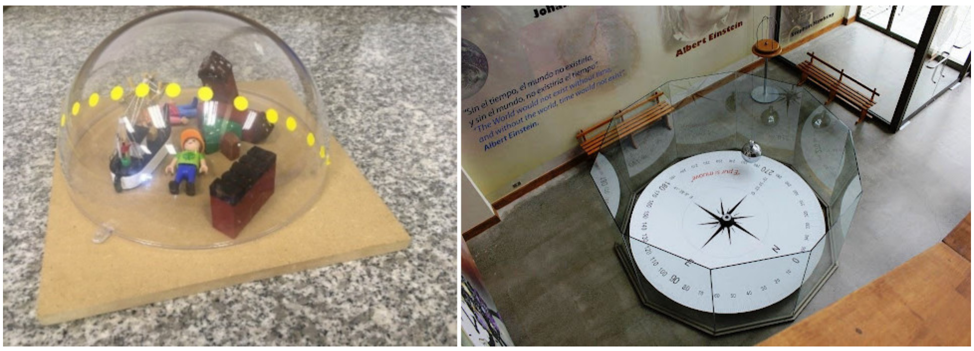
Possible activities (some may be complementary) include students producing simulated or photographic time-lapses or multi-exposures during the day for various seasons, e.g. one in summer and one in winter. For photographs, they need a clear sky. Producing such visualizations is easier and independent of weather conditions if they use a software like Stellarium.

In addition, children can produce hands-on scale models of the Sun crossing the sky. They can glue several circles representing the Sun placing on a semi-spherical transparent dome. The figure above represents the apparent movement of the Sun in winter and summer. This movement can also be illustrated in several complementary ways.

At night, the apparent movement of the stars around the southern celestial pole show us how the Earth rotates under the sky. During the day, an activity with a Foucault pendulum helps to witness the rotation of the Earth. Students can create a time-lapse that illustrates the variation of the angle with respect to the pendulum's plane of oscillation. Finally, adequate software like Stellarium, star map or skywalk helps to visualize the effects we see due to the Earth's rotation.

Now, we are alone in the Universe and we move very fast.

Top left: Image obtained by students from the Christopher Clavius Observatory. The sea of tranquility is just visible. Top right: Masks to explain why we only see one side of the Moon. Bottom left: The Sun and sunspots obtained by students at the school's observatory. Bottom right: The Moon photographed by day.



Left: Work that students can develop to show the apparent path of the sun in the sky from Puerto Montt. Right: Foucault pendulum from the school to show the rotation of the Earth.

The Globolocal Project and the Use of the Parallel Globe

Speaker: Nicoletta Lanciano, Università di Roma "La Sapienza" e Gruppo di ricerca sulla pedagogia del cielo del MCE (Movimento di Cooperazione Educativa), Italy

From didactic research we fund initial conceptions with big difficulties in understanding the point of view of astronomy, geometry, physics, and geography about the spherical Earth. With a globe in the same orientation like the Earth in space, the Parallel Globe, we observe fundamental astronomical relationships between Earth and Sun, in real time. The international Project Globolocal is democratic, because we distinguish concepts like high-low, above-under and North-South. Each location, seen from the place of observation, is at the top of the world, so it helps to have a correct image of the Earth in the space.

Talk link: https://youtu.be/qTvZVTIl14k

I presented the Globolocal Project and the use of the Parallel Globe that is a tool for working on Astronomy during the day, but not only that. We also work with the Sun and in the open air. It means that we must wait for a sunny day with no clouds. It is an ecological aspect of our work because we must be patient and wait and recognize that we depend on nature. Being in the open air is a very important aspect of our health and our wellness, meaning that school is also conducted in the open air, in a garden, and not only in the classroom.

The Parallel Globe allows many didactic approaches at different levels, with children, young students, and adults because we know from research that adults also have difficulties explaining quotidian astronomical phenomena. The Parallel Globe is very easy to construct: we remove the usual terrestrial globe from its stand, fixed and universal. It is enough to place the globe on a cup, well oriented with a compass, with the North Pole to the North and the South Pole to the South, and our location on the top: in fact, anywhere we are, the entire planet is below our feet.

If I am in Rome - Italy at 42° North, I put the globe with Rome on the top. However, if I am on the Equator, in Kenya or Colombia, the terrestrial axis is quite horizontal and if I am near the South Pole in Antarctica, the axis is rather vertical. So, everybody and every country are in turn at the top of the world and in the part of the globe facing up.

We can put the globe on a cup, or we can build a new flexible stand. With this globe, it is evident that "north-south" is different from "high-low" and from "up-down"! Instead, the fixed globe makes us think that there is an absolute up and down. The Parallel Globe helps us to see that "North" is a global geographical reference, while "up" is a local and physical indicator. Then, we put the Parallel Globe in the same position that the Earth has relative to the Sun. The globe and the Earth are in a homothetic orientation, and the globe assumes the same position as the Earth has in space. So, the Sun illuminates one half of Earth's sphere and one half of the sphere of the globe, with the same countries in light and in shadow. This instrument allows us to see the Earth from outside because in every moment the model is illuminated like the planet.

It helps us to find the connections between the local topocentric perspective and the global geocentric one; to reflect on a heliocentric global view: our local situation is considered in a global dimension. In fact, we can observe on the Parallel Globe where it is midday and the shadow of a gnomon disappears, where it is night or day, where they have sunset, or sunrise, and much more. Observing the Parallel Globe several times a day, and several days in a year, we can see which elements vary and which remain constant.

If we observe the terminator, that is a great circle of the sphere, that separates the light from the shadow, we see the direction of Earth's rotation. We can also measure and calculate how many hours of light we have in a day, related to the local latitude and the period of the year. Looking at this instrument is very different from studying these phenomena in a book and repeating a phrase from memory; it is much stronger from the point of view of emotion, of astonishment, of memory.

The Parallel Globe lets us travel to all the countries of the world. If we live in the North, we can see what happens in Ecuador or in South America. If it is daytime, we can see where, now, it is night. If it is Summer for Italian people, we can see where it is Winter, for example, in South Africa. For this reason, it is an instrument and not just a model of the Earth. It helps us to ask questions and to find answers. Why the name "Parallel Globe"? Because the axis of rotation of the globe is set in the same direction that the Earth has. The angle between the axis and the horizontal plane is equal to the latitude. At every point of the planet, the horizontal plane is parallel to the tangent plane of the globe. If we put some toothpicks or pieces of plasticine in a radial position as gnomons, we see their shadows, with their direction and longitude, with reference to the inclination of the Sun's rays. We can put more gnomons on the same meridian, in places with the same longitude, or on the same parallel, in places with the same latitude. With the Parallel Globe we can work on common errors and difficulties: for example, we can approach problems with perceptive and cognitive difficulties like "why don't people in Argentina fall off?". And we can see that at noon, even at a Summer Solstice, in most places, the Sun is never at the Zenith, like a lot of young and adults for example in Europe think! And Summer is not due to the position of the Earth being closer to the Sun. In fact, we have two different hemispheres that are in different seasons at the same time.

Globolocal is a Project developed by Italian and Argentine researchers, for teaching Astronomy and for helping understand astronomical phenomena, with attention to different countries in the world with their geographical and astronomical differences, from the Equator to the Poles. Usually, representations and models refer to the Northern Hemisphere as if it were universal: this is a problem of power and furthermore causes many difficulties in comprehending astronomical phenomena for many. On the web site of the Project we collect photos, didactical experiences and reflections about the use of the Parallel Globe. The website `www.globolocal.net`, is now under revision.

But above all, the Parallel Globe returns to each and everyone their position on top of the world and that is why it is a democratic tool! Democracy means to recognize the dignity of every position in the world and also the dignity of every language. "The school has the task of stimulating a profound awareness of the interdependencies of our being in the world and of promoting a responsible awareness of the local dimension in the planetary dimension." (MCE)

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The Eratosthenes Experiment: a 2300-Year-Old Ingenious Measurement

Speaker: Angelos Lazoudis, Ellinogermaniki Agogi, Pallini, Athens, Greece

In ca. 240 B.C., the Greek astronomer Eratosthenes made the first good measurement of the size of Earth. By noting the angles of shadows in two cities on the summer solstice and by performing the right calculations, he was able to make a remarkably accurate calculation of the circumference of Earth. In our educational activity, students repeat the experiment by using e-learning tools, simple instruments, and a platform (eratosthenes.ea.gr) that allows schools to collaborate with each other. Our aim is to turn this international activity into an important world event, giving students, teachers and educators from around the world the opportunity to actively engage in building online learning communities, exchange ideas and material through innovative initiatives.

Talk link: https://youtu.be/Fs4pC1KniMc

Over the past, many methods highlighting science education have been proposed for measuring the Earth's radius. Proposed experiments are based on pure mathematics (e.g. the Al-Biruni method) or even on using modern technology, e.g. a digital camera.

We follow the steps of Eratosthenes, who was an astronomer, scientific writer and chief librarian at the Library of Alexandria. In ca. 240 B.C., Eratosthenes made the first good measurement of the size of Earth. By noting the angles of shadows in two cities on the summer solstice and by performing the proper calculations, he made a remarkably accurate calculation of the circumference of Earth.

In our educational activity, students repeat the experiment using e-learning tools, simple instruments, and a platform (http://eratosthenes.ea.gr) that allows schools to collaborate.

The main objectives of our proposed educational activity are to:

- Describe the geometry of how sunlight strikes Earth at different latitudes
- Describe how the circumference of Earth was first measured millennia ago
- Describe how to determine local noon
- Measure the angle of the Sun at local noon
- Collaborate with another school some distance away to determine the radius of Earth.

We use two different types of tools: Map tools such as Google maps or Mapmaker offered by National Geographic, and Tools for calculating the local noon time such as Stellarium or the NOAA solar calculator. The latter tools provide us with the necessary information as the experiment needs to be performed at local noon when the Sun reaches the zenith.

The proposed day for the experiment is during the spring equinox day, on March 21st 2022, because we know that on that day, the solar rays fall perpendicular on the equator. Thus, the distance that needs to be calculated between any school and the place where the rays fall on the ground at 90 degrees is the one from the school to the equator.

As schools register with their geographic coordinates, we match those sharing the same or close longitudes to perform the experiment collaboratively on March 21st or any other day. When two schools are matched, they measure by following Eratosthenes' steps, the angle corresponding to the arc distance between their school and the equator. By sharing measurements and using simple geometry, they can relate the difference of the two angles to the distance between the two schools. Having exchanged this data leads to calculating the Earth's radius by using the mathematical rule of three.

Our presentation provides sample recordings from previous events with schools that shared a common longitude but were far apart, e.g. a school in Athens (Greece) and another in Vantaa (Finland).

Moreover, we exhibit some photos from Antarctica. During the spring equinox, the solar rays are parallel to the ground making the shadow of an object – in theory – almost infinite. Our photos were taken by Robert Schwarz outside the Amundsen-Scott station located precisely at the South Pole. Robert's (being 1.83 m tall) shadow is estimated to be more than 100 meters long!

The Eratosthenes experiment is usually followed by a photo competition. The competition is open for teachers, and the winning prize is a trip – with all expenses covered – to the DiSTARS summer school. (http://www.distars.eu)

Our aim is to turn this international activity into an important world event. It gives students, teachers and educators from around the world the opportunity to actively engage in building online learning communities and also exchange ideas and material through innovative initiatives.

Analemmas in Education

Speaker: Vegard Lundby Rekaa, NAEC-Norway, Norway

Analemmas are fascinating. Their shape arouses curiosity about what it can mean, while knowledge of their origin challenge an old notion that the sun is always in the same place at noon, every day. From the analemma, it is possible to calculate simple quantities such as the latitude of where they are observed, as well as the inclination of the earth's rotational axis. It is also possible to deduce solar mean time is constructed, and that it is only exact on four days every year. The exercise taught in this session allows students to carry out measurements of the suns motions themselves and, based on these, calculate some basic quantities in the movements in our solar system.

Talk link: https://youtu.be/KMmaz3lCYWo

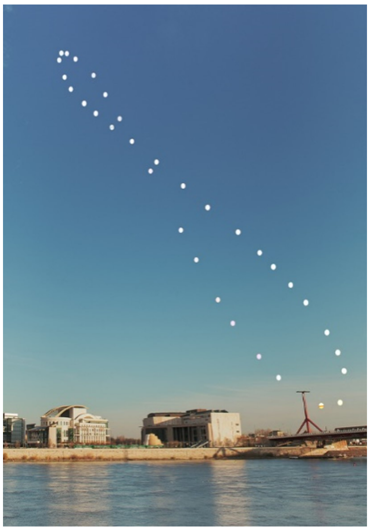
An analemma is created by observing the Sun's position every day during the year, at the same time each day. The observation can be done directly or indirectly using a sundial or a shadow from a pole.

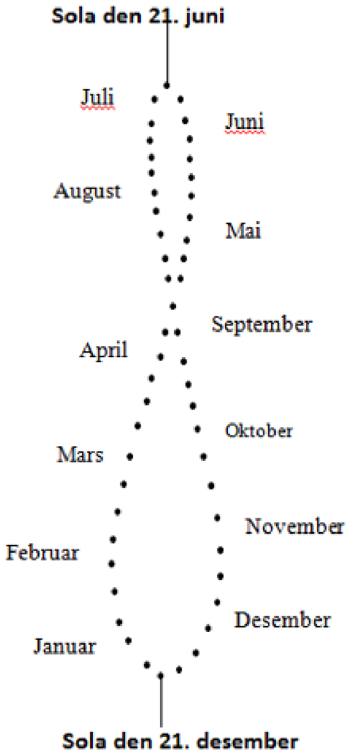
The analemma is a phenomenon well suited to use in education and demonstrates basic concepts in space and celestial mechanics. And it is an exciting way to observe the sky, even during daytime. The Sun is our nearest star and an object from which we have learned a lot about our own solar system and other planetary systems.

Whichever method you choose to make an analemma: the resulting geometrical shape you get is something close to a figure eight. Most people are aware that the Sun varies in height during the year but believe that the Sun is directly towards the South (or the North if you are in the southern hemisphere) at noon. This last detail is only true on four days each year! By finding a way to record the actual position of the Sun each day at noon, we get pictures like the ones shown in the Figures.

The primary reason for the change in the Sun's position, and the "motion" in the analemma, is due to the tilt of the rotational axis of the Earth. This causes the Sun to pass high in the sky at noon during summer, and low in the sky during winter. As a result, we find a vertical "motion" of the Sun's position when compared to the days before and after. The Sun will thus mark the top and bottom turning-points of the analemma during the summer and winter solstices.

The secondary "motion" of the analemma, sideways, is an expression of the Sun not being exactly south (or north) at noon. Or put in other words, the Sun is not on the meridian! Most of the year, the Sun is either ahead (i.e. passing the meridian before noon) or after (i.e. passing the meridian after noon).





This is caused by two horizontal motions that do not follow the mean solar time, or the expectancy that the Sun has completed one lap around the skies during 24 hours. These motions can be explained by the tilt of the rotational axis and the ellipticity of the Earth's orbit.

One day is defined as one rotation of the Earth around itself, measured relative to the Sun's position in the sky. The rotation of the Earth is, however, not just 360 degrees. During one rotation around its axis, Earth also moves approximately one degree on its orbit around the Sun, thus leading to a 361 degree rotation during one day.

Earth's rotation is not in the same direction as its orbit. Instead, the rotational axis of the Earth is tilted by 23,5 degrees with respect to the ecliptic. This causes a seasonal variation in the final contribution of the one-degree rotation since time is defined and measured along the equator.

Near the solstices, the Sun is either high or low in the sky, with little change in height from one day or the other. On such days, the equator appears parallel to the ecliptic. This causes the 1-degree contribution to be at its largest since none of the orbital motion is vertical with respect to the equator.

Near the equinoxes, the orbital contribution (one degree) is 23,5 degrees off the equator. Therefore, only a component of the motion contributes to a movement that can be measured in hours and minutes, i.e. parallel to the equator. The orbital contribution is thus reduced by 10%.

This gives us the impression that the Sun slows down during spring and autumn, and the Sun will be crossing the meridian later during the day. During winter and summer, the Sun "speeds up" again. Just before the seasons change to autumn or spring, the Sun races ahead and crosses the meridian before noon.

The final velocity component that causes the Sun not to be in the South (on the meridian) at noon comes from the slightly elliptic shape of the Earth's orbit. As the Sun is somewhat closer to the Sun during winter (in the northern hemisphere) and further away during summer, the Sun moves faster around the Sun during winter than it does during summer. The difference in distance and velocity is merely 3% (measured relative to the average distance and orbital speed). Still, this contribution is enough to give the analemma the asymmetry between the winter and summer lobes of the "figure eight".

You can make an analemma too!

The easiest and safest way is to attach a horizontal pole on a wall facing southwards. Make sure that the pole is steady and can withstand wind, rain and snow. Put also a ball, a plate with a hole, or a cross at the end of the pole. This makes it easier to mark the exact position of the shadow from the tip of the pole on to the wall.

Add marks with a pen or a marker every day you have sunlight. Remember to get someone to help you if you are away for several days. It is best if you can get 2-3 markings every week. Good luck!

Observing Solar Eclipses

Speaker: Sarah Abotsi-Masters, NAEC Ghana, Ghana Planetarium, Accra, Ghana

A solar eclipse is one of the most awe-inspiring spectacles that can be witnessed. The recommended method for viewing an eclipse safely is using eclipse glasses or a telescope fitted with a solar filter. But these tools are not available to the majority of people around the world. This talk will showcase two simple methods (pinhole and mirror projection) for viewing a solar eclipse using household objects, thus making eclipse viewing easy, affordable and accessible.

Talk link: https://youtu.be/9Q6RR4xwwfI

A total solar eclipse is possibly the most spectacular and awe-inspiring astronomical phenomenon that can be witnessed. There are between 2 and 5 solar eclipses each year worldwide. However, any given location will experience a solar eclipse on average only once in around 400 years, so if you have the opportunity to see one, make sure not to miss it!

Solar eclipses provide a unique opportunity for science communication to the general public. This is particularly important in areas where scientific literacy is generally low. For example, in Ghana, where I live, there is virtually no science journalism. It is very rare to see or hear articles about science or astronomy in the mass media. But the total solar eclipse of March 2006 made headlines across the country!

The geometry of a solar eclipse provides a multiplicity of rich teaching opportunities since, in order to explain how a solar eclipse occurs, it is necessary to explain the relative sizes of the Moon and Sun, the relative distances of the Moon and Sun, the phases of the moon (since the eclipse occurs at new moon), the elliptical shape of the moon's orbit (annular eclipse) and the inclination of the plane of the moon's orbit (the reason we do not have solar eclipses every month).

Many organisations have developed resources and activities that demonstrate the true scale of the Earth, Moon and Sun, e.g. Astronomical Society of the Pacific and NASE (Network for Astronomy School Education); see resources below.

So the aim is to encourage as many people as possible to observe a solar eclipse when one occurs in their region. The specially-designed eclipse glasses are the "gold standard" for eclipse viewing. However, in many regions, they may not be easily accessible or affordable. Hence it is extremely important that communication about eclipses includes how to view the eclipse SAFELY without eclipse glasses. (And it is the partial phase being referred to here since, during the period of totality, the Sun can be safely viewed with the naked eye).

Fortunately, there are simple ways to do this, and I will outline two methods; basic pinhole and reflected pinhole.

The great advantage of the pinhole viewing method is that there is no need to build, buy or make any special equipment, since any household utensil with small holes (no more than a few millimetres) in it will do, such as a colander, grater, or straining spoon.

The pinhole method works because an illuminated object reflects light in all directions. A pinhole is small enough such that only the rays that travel directly from different points on the object can pass through and hence form an image of the object on a surface on the other side.

If you have no utensils to hand, there are many other ways to produce pinhole images, e.g. simply make a small hole in a piece of paper, use the small spaces between interlocked fingers, or use natural features such as the spaces between leaves on a tree. The end result is that light from a partially eclipsed Sun, passing through the pinhole, will produce an image of the Sun on the ground or a sheet of paper placed a metre or so away. You can vary the distance between the pinhole object and the ground or paper to get sharper or brighter images. You can even get creative and create pictures using a pattern of holes!

The reflected pinhole method requires a little more effort to set up, but can also give good results, and has the advantage of producing a larger image that many people can enjoy. Take a mirror, cover it in paper or tape, leaving a gap (a pinhole) of just a few millimetres. Position the mirror so that it reflects sunlight onto a screen or wall, preferably inside a darkened room. You can experiment with the size of the pinhole and the distance to the screen; a smaller pinhole produces a sharper image, but it will be less bright. A greater distance to the screen should produce a larger image. The mirror will need to be taped or held in place with blu-tack or similar to keep it steady.

These simple, accessible and affordable methods enable people anywhere and everywhere to have an amazing experience viewing the eclipse safely, a once-in-a-lifetime opportunity they will never forget!

Resources:

- Easy pinhole methods: https://www.africanastronomicalsociety.org/solar-eclipse-2020/easy-pin-hole-methods-to-view-the-eclipse/
- Safe viewing methods: http://www.eclipseafrica.org/Info/WatchEclipse.shtml#PinholeTrees
- Worksheet to explain how pinhole projection works: http://www.eclipseafrica.org/Info/PinholeProjectionFocus.pdf
- Reflected pinhole method: http://www2.eng.cam.ac.uk/~hemh/transit.htm
- Yardstick eclipse activity: https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=327
- Yardstick eclipse activity document: https://nightsky.jpl.nasa.gov/docs/ModelMeaningfulEclipses2016.pdf
- Phases and Eclipses from NASE: http://sac.csic.es/astrosecundaria/en/cursos/formato/materiales/conferencias/T3_en.pdf

Reckoning Earth's Size by Taking a Dip: A Hands-on Site-based Learning Activity

Presenter: William H. Waller, IAU/OAE/US-NAEC, Endicott College and The Galactic Inquirer, USA

An engaging technique for determining the Earth's size makes use of one's local horizon and its dependence on one's height. I have made use of a nearby beach, from which a stone breakwater is visible near my local horizon. Equipped with binoculars, I slowly walk into the water while sighting a piece of the breakwater that appears just above my horizon. As I descend, I watch for the moment when that piece just submerges below my apparent horizon. The measured height from the waterline to my eyes is related to the distance of the breakwater and the Earth's radius by the Pythagorean theorem, and so I can readily calculate the radius of Earth. Over several years, I have successfully engaged high-school students in conducting this experiment amid a wide variety of ocean conditions.

Poster link: https://youtu.be/MrDVMjmKHy0

Many astronomy educators have taught the famous experiment by Eratosthenes (250 BCE), whereby he estimated the circumference of Earth by comparing the angle of the Sun at noon on the Summer Solstice as observed from Syene (Aswan) vs. more northerly Alexandria in present-day Egypt. A similar experiment can be conducted nowadays by measuring the solar angle at any time simultaneously from two locales that are located at the same terrestrial longitude but are separated by a known distance of several hundred kilometers. The key to ensuring simultaneity is to preset the date and time to observe the Sun from each site or, equivalently, to communicate live between the respective observers via cellphone.

An alternative approach to reckoning the Earth's size can be done solo, without the need for another observer located hundreds of kilometers away. This approach makes use of one's local horizon and its dependence on one's height. I have made use of a nearby beach, from which a stone breakwater is visible near my local horizon. Equipped with binoculars, I slowly walk into the water while sighting a piece of the breakwater that appears just above my horizon. As I descend, I watch for the moment when that piece just submerges below my apparent horizon. By noting where the water line was on my body, I can then use a meterstick to measure the distance between the waterline and my eyes. That height is related to the distance of the breakwater and the Earth's radius by the Pythagorean theorem, and so one can readily calculate the radius of Earth.

Over several years, I have engaged high-school students in conducting this hands-on site-based experiment amid a wide variety of ocean conditions. That means having a few good pairs of binoculars available for use. I have learned that the trick to getting good results is to make sure that the student is spotting a piece of rock that is just barely above their local horizon and then tracking that piece while descending until it just barely disappears from view. If done correctly, one should be able to determine the radius of Earth to well within 10 percent of its nominal value (6387 km). You can view an example of this exercise at https://sites.google.com/site/sciencegazette/presentations

If an open sea is not available to you, a similar experiment can be conducted on flat land by making use of some object that appears near one's local horizon and is at a known distance from you. You will have to find some way to adjust and measure the height of your eyes (or camera) to make this method work.

Using Innovative Technologies to Study the Sun

Presenter: David Lockett, IAU-OAE NAEC USA Team, Space Station Explorers, Astronomy in Chile Educator Ambassador, NASA Solar System Ambassador

Our sun, a dynamic star, varies constantly. It also produces energy and solar wind that impact us on Earth. See how students can discover the ever-changing power of the sun through innovative technologies such as VR, 3D printed images, Helioviewer and NASA's Space Weather Action Center. How do you create hands-on and engaging activities to teach about the Sun? Virtual reality, 3D printing and dynamic images of the Sun will be used to teach important concepts related to our dynamic star, the Sun.

Poster link: https://astro4edu.org/siw/p43

Space. It is this wonderful, exciting thing to explore for students. Astronomy is an interesting subject to tackle in the early years. Kids love to look up at the stars at night, especially if they get to stay out past bedtime! Interactive computer exercises and hands-on activities encourage questioning, experimentation and exploration and accommodate diverse learning styles.

You can introduce astronomy concepts through a variety of hands-on demonstrations and art projects. You can teach a simple astronomy unit that covers topics like: Observation, Stars, the Sun, and our planet Earth.

You can explore the principles of astronomy through hands-on demonstrations and projects that display the concepts in action. Observe the sun through Parker Solar Probe and use Merge Cube to learn more about how NASA is studying the sun's Corona. The Sun is a yellow dwarf star at the center of our Solar System. All the planets of the Solar System orbit around the Sun. The Sun and the Solar System orbit around the center of our Galaxy, the Milky Way. The Sun is a star, the only one we can see during the daytime. When we look in the night sky, we see endless dots of light, every one of them is a star just like our Sun.

Children learn about the layers of the Sun and discover how Earth's magnetosphere acts like a giant shield to protect us from all kinds of space weather from the Sun's activity. Introduce your students to the astronomy curriculum focusing on the Sun. This poster session contains engaging inquiry-based and hands-on science activities developed specifically for learners in the primary grades.

Daytime Astronomy with CLEA Resources

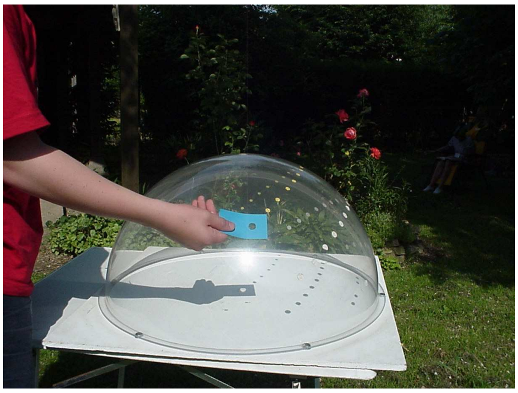
Presenter: Frédéric Pitout, Observatoire Midi-Pyrénées, Université Toulouse 3 – Paul Sabatier, Toulouse, France, Comité de Liaison Enseignants et Astronomes (CLEA)

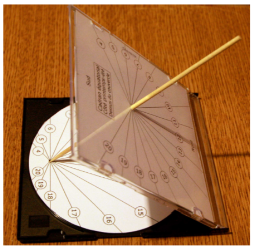
Organising a night-time observing session in schools is not always easy for various reasons: logistical issues, lack of equipment, etc. Yet, we tend to forget that observing our Sun is also a great way to study astronomy. In this poster, we shall present a few activities used by CLEA and detailed in a book, entitled The Sun, issued in 2018. Some of those activities are very easy to carry out with very little material; some require some more elaborated equipment.

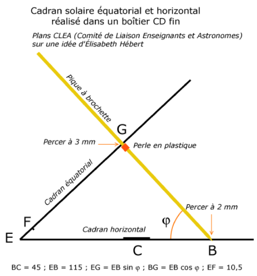
Poster link: `https://youtu.be/yRj0j0mlRjk`

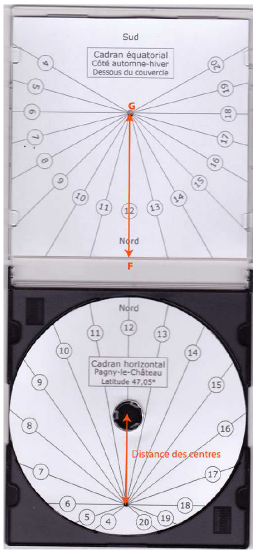
Teachers sometimes tend to forget that they may practice astronomy during the day. We present in this document two activities produced by CLEA, the Liaison Committee Teachers and Astronomers, which is a non-profit organisation that has promoted astronomy in education since 1976. The first activity is about studying the path of the Sun in the sky with a salad bowl; the second one explains how to build a sundial with a CD case.

The path of the Sun with a salad bowl: The idea here is to avoid any tricky spherical to planar projection problems and model the celestial vault with a transparent salad bowl. The virtual









observer is at the centre of the circle. Therefore, the location of the Sun on the bowl is correct when the shadow or the image of the Sun reaches the centre of the circle (see figure below). The students mark, with a marker pen or small stickers, the location of the Sun on the salad bowl during the course of the day, every 30 min or so. To obtain the two extreme trajectories, this should be done several times at various times in the year, ideally at solstice and equinox. Having done all this, the students may draw several conclusions. i) The trajectory of the Sun is longer (longer day) in Summer than in Winter; ii) all trajectories are parallel to each other (and in fact perpendicular to the rotation axis of the Earth; iii) one may determine the latitude of the place from the inclination of the trajectories.

A sundial with a CD case: Here, we use a cheap CD case as a sundial. The angle between the two parts, one being horizontal and the other perpendicular to the Earth's rotation axis, is set to equal the location's latitude. In both parts of the case, we insert the dials (available on the CLEA website) available for several latitudes. The equatorial sundial, in the inclined part of the case, consists of two dials: one for Spring-Summer when the Sun is above the celestial equator, and another one for Autumn-Winter when the Sun is below the celestial equator. A stick is inserted as a gnomon, and a small pearl blocks the CD case in the right location. When all set and the sundial are correctly oriented, the stick casts its shadow on the two dials (horizontal and equatorial) and indicate the local solar time.

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Discussion summary

During the live panels following the talks, most of the comments from the audience were positive. They indicated the participants could take away many valuable ideas of teaching astronomy with very simple and powerful tools. However, a discussion sparked over the choice of language used during the workshop. All speakers and participants agreed that even using English as a default language constitutes a significant barrier for many skilled educators worldwide and misses out on much of the expertise available globally.

We learned about Zero Shadow Day. Any location between the Tropics of Cancer and Capricorn sees the Sun at zenith twice a year, when objects do not cast a shadow at local noon. This day may serve as an opportunity to advertise astronomy in many countries.

The session host received a comment from one participant that most of the talks focused on observing the Sun. Asking about other daytime activities, e.g., with the Moon, we learned that one could relate the lunar phases to the angular separation between the Sun and the Moon.

During the discussion, we also learned about an astronomy teacher network in Chile. Their activities are listed on the webpage https://redastropp.blogspot.com, together with a selection of school exercises in Spanish.

A collection of activities, available in Italian, is connected to the highly praised "Parallel Globe" tool. Our partners from the OAE Center Italy are willing to help with translations.

Earth as a Planet

Session organiser: Dario del Moro,
Department of Physics, University of Rome Tor Vergata, OAE Center Italy, Italy

Session overview

Apart from being the cradle of humankind, Earth is also the third planet of our Solar system. This allows us to apply the astronomer point of view to it, and this point of view is the leading topic of the "Earth as Planet" session. This point of view has at least two different declinations, which were both explored in the session: the source of the awareness that we are all "under the same sky", and the consciousness that the physical laws that apply here are the same as elsewhere, and therefore we can learn about our world by comparing it to the others planets.

To represent the first point of view, we had two talks by Mike Simmons and George Miley. They presented ideas and methods to convey this ‘cosmic awareness’ to inspire fraternity and motivate the young.

For the second point of view, strongly related to the climate change issue, we had two talks by Jeff Bennet and William Waller. They introduced ways to advance the public understanding of global warming, with a positive approach, leveraging on our inspirational role as scientists.

On October 13, 2021, actor William Shatner – Captain Kirk of the Enterprise – had his first real orbital flight experience. His first words after exiting the capsule? **"Everybody in the world needs to do this. Everybody in the world needs to see this."** Once again, we went into space and came back with the awareness that this world is fragile and we should take care of it, together. To solve the problems, together.

TALK CONTRIBUTIONS

Astronomy and the Overview Effect

Speaker: Mike Simmons, Affiliate Research Scientist, Blue Marble Space Institute of Science, USA

Upon seeing Earth from space, astronauts often experience the overview effect, a profound shift in their understanding of Earth as a fragile oasis of interwoven and inseparable systems in the vastness of space. But fewer than 1000 of the Earth's billions of inhabitants have had the opportunity to observe Earth as a planet among the stars first-hand. Astronomy gives us a way to bring the overview effect down to Earth, providing a sense of our traveling through space together. This planetary identity is essential if we are to solve the many problems of Spaceship Earth such as climate change, pandemics, and profound inequity. The overview effect, however it is experienced, is the key to advancing from "us and them" to "we."

Talk link: https://youtu.be/KEbgV_HFtuo

Humanity must rise above the earth, to the top of the atmosphere and beyond. For only then will we understand the world in which we live. – Socrates

The overview effect, coined by author Frank White in his book of the same name, is the cognitive shift experienced by many astronauts who see Earth from space. We all understand the planetary nature of Earth intellectually. Images from spacecraft, like Earthrise from Apollo 8 and the Pale Blue Dot from Voyager 1, have shown it to us. But we do not really internalize it as part of our existence. Like the Copernican perspective of the Solar System, it is something we know to be true, something we can prove and understand, but that we do not experience directly by seeing it for ourselves from outside. Astronauts on the International Space Station spend much of their spare time Earthgazing. The view of Earth changes constantly, and astronauts describe it as giving the impression of a dynamic, living organism. They describe Earth's atmosphere as "paper-thin", the Earth as appearing fragile, and the dynamic systems of the planet as clearly interconnected. They often return with a new appreciation for the Earth as a planet, and for the connection between humanity and nature. While the lack of visible borders is often quoted as being an important aspect of the Overview Effect, there is much more to it. Astronauts also see Earth surrounded by stars, as a planet embedded in the immensity of the Universe. When asked about this, astronaut and astrophysicist Jeff Hoffman replied, "You do, from that perspective, see the Earth as a planet. You see the Sun as a star. We see the Sun in a blue sky, but up there, you see the Sun in a black sky. So, yeah, you are seeing it from the cosmic perspective."

The nature of our dependence on each other is not new. R. Buckminster Fuller wrote, "We are all astronauts on a little spaceship called Earth." Marshall McLuhan added, "There are no passengers on Spaceship Earth, we are all crew." Observing Spaceship Earth from outside, experiencing the overview effect, the intellectual concept becomes reality. It is clear, tangible, palpable, even obvious. But fewer than 600 people have seen the Earth from space. Private flights and virtual reality will help bring the experience to a few more. What about the rest of humanity?

The answer is in the stars. Astronomers look into space from Earth, watching our motion among the planets and our place among the stars. When we see the Moon rising, we know others half a world away are watching it set. When we explore the cosmos with telescopes, we look out at our cosmic environment. We see that we are in space, orbiting the center of mass of the Milky Way galaxy along with billions of other stars. We see the immensity of the Universe and we understand that we are a part of it. Astronomers have a unique perspective, a cosmic perspective. While we do not leave Earth in body, we travel through our local and distant neighborhoods. We are familiar with planets and can see how the Earth is one. We experience what others do not. The passion to share that perspective with others – bringing our telescopes to the streets for people to see the Moon, planets, and more up close for themselves – is not just about sharing a hobby. It is sharing the cosmic perspective that reveals our planetary existence. Those first views of the cosmos through a telescope can be life-changing. Astronomy is the overview effect for those of us who will not make it into space. And it is available to everyone on Earth.

Astronomy is more than a modern-day hobby. It has been a part of all cultures throughout time. There are astronomy enthusiasts everywhere, and sharing the special perspective they have gained is a passion unique to astronomy. The Blue Marble image taken from the Moon by Apollo 8 astronaut Bill Anders started a global movement of environmental awareness, including Earth Day. Anders said, "We came all this way to explore the Moon, and the most important thing is that we discovered the Earth." The Pale Blue Dot image taken by Voyager 1 while six billion kilometers from the Sun shows us the Earth as, in Carl Sagan's words, "a very small stage in a vast cosmic arena." From space, Earth is not "down there." It is "out there", like any other planet. This is a critical part of the overview effect experienced by astronauts. Astronomers understand it as well.

I have found a special connectedness between astronomers around the world based on our common experiences. Our cultures may be different, but the practice of astronomy is the same. We share the same sky. We share that sky with our ancestors as well. We may have different myths about the sky and make different constellations, but even those are created for the same reasons. We feel connected with the stars. We always have. The community of astronomers is truly global, connected by something universal. We can – we must – share what we have with others. We hear "We are all in this together" all the time but even those who say it fail to act like it. The Overview Effect is a paradigm shift that engenders a true sense of interconnectedness and interdependence in the few who have experienced it. Astronomy is the overview effect for the rest of us. More on the overview effect at the Overview Institute website: www.overviewinstitute.org. Watch Overview, a short film on the overview effect by Planetary Collective: https://vimeo.com/55073825. More details on the Center for Planetary Identity: https://www.planetaryidentity.com/.

The "Pale Blue Dot - Universe Awareness" Programme for Very Young Children

Speaker: George Miley, Leiden Observatory, The Netherlands

This talk will demonstrate how exposing children to the wonders of the Universe at an early age can inspire them and contribute uniquely to advancing several of the United Nations Sustainable Development Goals. I shall discuss the rationale for reaching out to children aged 5 to 10 and describe the use of such an approach in the Pale Blue Dot - Universe Awareness project. UNAWE was initiated in 2005 with a main goal of stimulating a sense of global citizenship from a young age. It has since been implemented in more than 60 countries. Pale Blue Dot is building on Universe Awareness and will in addition focus on advancing each of the SDGs, with a set of appropriate materials and modules.

Talk link: `https://youtu.be/Xwub8vHU4Bg`

Exposing children to the wonders of the Universe at an early age can excite and inspire them and contribute uniquely to advancing several of the United Nations Sustainable Development Goals, particularly SDG4.7 – stimulating a sense of global citizenship.

The survival of our planet is threatened by many global dangers that can only be tackled by cultivating globalism and adopting a global approach. These dangers include human-induced climate change, pandemics, the risk of nuclear war, clashes between rival ethnic groups, increasing political polarization, and extreme nationalism. There is therefore a need to cultivate a sense of global citizenship, tolerance and solidarity throughout the world. Promoting a world view in young children at an age when their value systems are beginning to form is one of the most effective tools for doing this.

The strategy of targeting young children to promote the message of global citizenship derives from evidence that:

1. Ages 5 – 8 are crucial in brain development and is a crucial period in the development of our value systems (Brierley & Barlow, 1994),

2. Early childhood education contributes to global development (Samuelsson and Kaga, 2007, Shonkoff, et al. 2007),

3. The social effectiveness of education is greatest for the youngest children (multi-decadal study by Nobel Prize-winning economist James Heckman and colleagues (Heckman et al, 2009).

This evidence was the rationale for initiating the Universe Awareness programme (UNAWE) and its follow-up project Pale Blue Dot-Universe Awareness (PBD-UNAWE). UNAWE was started by

Leiden University in 2005 with the main goal of stimulating a sense of global citizenship from a young age. It has since been implemented in more than 60 countries, and was the basis for two projects funded by the European Research Council (e.g. EU-UNAWE Team, 2015). "Pale Blue Dot" (PBD-UNAWE), founded in 2018, builds on Universe Awareness and also focuses on advancing several of the UN Sustainable Development Goals, in addition to SDG 4.7 on globalism.

The philosophy of PBD-UNAWE is encapsulated in three quotations by Carl Sagan:

1. "Fanatical ethnic or national chauvinisme are difficult to maintain when we see our planet as a fragile blue crescent fading to become an inconspicuous point of light against the bastion and citadel of the stars." (SDG 6 – Peace).

2. "Look again at that dot. That is here. That is home. That is us. It makes clear our responsibility to deal kindly with one another, and preserve and appreciate the pale blue dot" (SDG 13 – Climate).

3. "I wanted to be a scientist since my earliest school days. The crystallizing moment came when I first caught on, that stars are mighty suns, and how staggeringly far away they must be to appear to us as mere bright spots." (SDG 4 - Education).

A set of new materials and teaching modules for PBD-UNAWE is being developed by Cecilia Scorza at Munich, who is organizing a pilot project in 5 countries, together with local educators and astronomers. Pale Blue Dot has been adopted as a "flagship" project by the IAU OAD in Cape Town and is being managed by the IAU European Office of Astronomy for Development in Leiden. It is planned to translate the materials into several languages and cultures and to develop and distribute accompanying training tools for teachers.

In September 2020, during the 75th anniversary of the founding of the United Nations, the IAU European Regional Office of Astronomy for Development held a virtual UN GA75 Dialogue on "Astronomy for Global Citizenship" (https://astro4dev.eu/images/main/Dialogue_summary.pdf). The speakers included South African Minister of International Relations and Cooperation, Grace Naledi Pandor. All participants, including Minister Pandor, strongly supported the concluding statement of the Dialogue that was subsequently communicated to the UN Secretary General: **"Before they are 10 years old, every child should be introduced to pictures of our tiny earth from space and the inspiring notion that we all together inhabit a tiny planet in a vast wonderful universe. This will help foster their sense of belonging to a common humanity (SDG 4.7), encourage them to respect and protect the environment (SDG 13) and advance the cause of peace (SDG 16)"**

In summary, stimulating a sense of globalism among all people is crucially important for the survival of our planet and targeting young children with programmes such as PBD-UNAWE is one of the most effective methods of doing this. There is a great need to support such efforts. We hope to build up PBD-UNAWE gradually – first with the 5-country pilot project and gradually increase the scope of the project until the above UN Dialogue resolution can be implemented.

I am deeply grateful to the many gifted people who contributed enormously to this project over the years. They include but are not limited to: Mahbobah Ahmadi, Kevin Govender, Carolina Ödman, Premana Premadi, Rosa Ros, Teresa Riera, Pedro Russo, Cecilia Scorza, and Michelle

Willebrands (in alphabetical order).

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Astronomers' Role in Climate Education

Speaker: Jeffrey Bennett, Big Kid Science / U. Colorado (Boulder), USA

You may think of climate science as distinct from astronomy, but the differences are not so important to the public. Both disciplines use the same basic physics, and many aspects of climate science come from astronomy (e.g., Venus). In this presentation, I will focus on why the public popularity of astronomy gives us a unique platform for advancing public understanding of global warming. I will emphasize the importance of approaching the topic 'with inspiration, not fear', providing concrete examples of strategies for audiences ranging from school kids to the general public. Note: Many of the examples will be drawn from my book A Global Warming Primer, posted free online at globalwarmingprimer.com, and my free middle school climate curriculum (bigkidscience.com/climatechange).

Talk link: https://youtu.be/gtq3ERLCaB4

Global Warming Communication — Why Astronomers?: We are scientists. We may think of climate science as distinct from astronomy, but the differences are not so important to the public. It is "our" topic. Many of the key topics in climate science are also part of astronomy. For example, Venus and planetary science, Radiative transfer and the greenhouse effect, The Sun and its effects on Earth, Relevance to astrobiology, SETI, etc. Public interest in astronomy gives us credibility with the public. For those teaching college courses on introduction to astronomy/astrobiology, your class may be the only place where your students will learn about the science of global warming.

General Principles for Climate Communication: Maintain "radical civility" (as discussed by Travis Rector), which essentially means being respectful to your audience, even to those who may seem unreasonable to us. Be sure you always focus not only on science and consequences, but also on solutions, so that we are showing that there is indeed hope. Going along with that, your focus should be on inspiration not fear. This is a bit subtle, since global warming is scary, but keep focus on the fact that it is also solvable and our goal is therefore to inspire the action that will create the kind of world in which we will all want to live.

What is the "Future"?: Most people tend to think in horizons no more than a few years, and media discussions of climate change rarely go beyond about 2050. But, many or most of today's kids – and your kids/grand kids – are likely to still be living in the year 2100 and beyond. So it is important to focus on that longer time horizon.

Discussing the Science: "Global Warming 1-2-3": The climate *is* complex, but the basic science of global warming is actually as simple as "1-2-3":
1. FACT: Carbon dioxide (and other greenhouse gasses) makes Earth warmer than it would be otherwise (and the more there is, the warmer it becomes).
2. FACT: Use of fossil fuels (coal/oil/gas) is adding carbon dioxide to the atmosphere.
3. CONCLUSION: We expect global warming to occur.
And the data confirm that global warming is happening as the 1-2-3 science predicts.

Discussing the Consequences: There are many consequences, but I find it useful to separate them into five major categories:
1. Regional climate change
2. Increase in storms and extreme weather
3. Melting of Sea Ice
4. Rising Sea Level
5. Ocean acidification

Discussing the Solutions: Two basic steps to creating a "post-global warming world":
1. Stop making the problem worse, which means stop adding greenhouse gas to the atmosphere.
2. Find a way (e.g., future technology) to bring the CO_2 level back to something more reasonable, such as 350 ppm.

The first step requires replacing fossil fuels with other energy sources, and we already have three existing technologies that could allow us to still have just as much energy without causing further greenhouse emissions: Energy efficiency, renewables (wind, solar, etc.) and nuclear – must remain on the table as one of the potential solutions for global warming. Future technologies could do far more, including providing the energy needed for active carbon dioxide removal. For example, advanced biofuels, solar energy from space, nuclear fusion. And given a time horizon looking toward the year 2100, it seems almost inevitable that, by then, we will have the technology needed to provide clean, cheap, and abundant energy to all.

Inspire Your Audience to Action: Think about two possible futures:
1. Status quo, in which we will suffer severe consequences from global warming.
2. Rapid action, leading us to a post-global warming world.

Write a letter to your grandchildren that will be sealed in a time capsule for 50 years. What will they think of the actions you took today?

Resources:
For college students: Sections on global warming in my textbooks on astronomy (The Cosmic Perspective) and astrobiology (Life in the Universe).
For the public: A Global Warming Primer, posted freely at globalwarmingprimer.com
For middle/high school: free Earth/Space Science curriculum posted at grade8science.com; Chapter 7 focuses on climate change.
For kids: The Wizard Who Saved the World, more info at bigkidscience.com/wizard.
Free Totality app for solar eclipses includes section on global warming; more info and download links at bigkidscience.com/eclipse
Scale model solar systems provide a great way to help people obtain a "cosmic perspective" on our planet and also to understand many ideas of global warming. Available now to communities around the world. Information at voyagesolarsystem.org.

Comparing the Climates of Earth, Mars, and Venus – Educational Takeaways

Speaker: William H. Waller, IAU/OAE/US-NAEC, Endicott College and The Galactic Inquirer, USA

By comparing the atmospheres and climates of Earth, Venus and Mars, I have found a quantitative warming relation that scales with the 0.3 power of the carbon dioxide mass overlying each square meter of planetary surface. This relation is consistent with the more recent warming experienced on Earth due to human activities. Although the atmospheric photo-chemistry that underlies the observed warming is complex, K-12 students can still progress in their learning Ð from basic observations of rising temperatures and carbon dioxide levels to plotting quantitative relations, interpreting their significance, and deliberating over possible human interventions.

Talk link: https://youtu.be/gq2LjmfrpPg

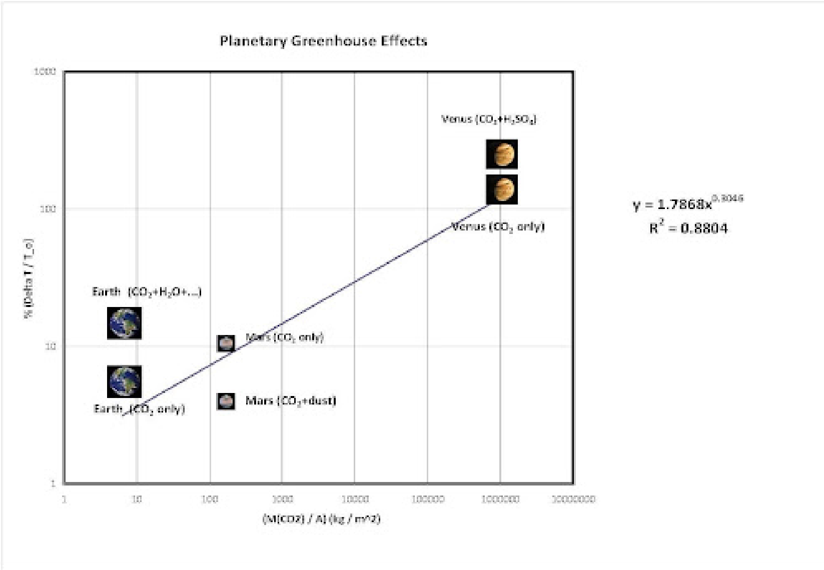

Figure 1: The relationship between percentile warming in Kelvins (relative to an atmosphere-free planet) and the surface density of atmospheric carbon dioxide for Earth, Mars, and Venus. Consideration of the warming produced by CO2 only yields a power-law relation with an exponent of about 0.3.

The signal has grown ever clearer. The Earth's atmosphere, oceans, and land masses have warmed by $1.0°$ C ($1.8°$ F) since pre-industrial times. Most of this warming has occurred over the past 50 years. The Intergovernmental Panel on Climate Change (IPCC) has concluded that human activities have prompted the bulk of this warming. The burning of fossil fuels, in particular, has increased the concentration of atmospheric carbon dioxide from 280 ppm in pre-industrial times to more than 400 ppm today – an augmentation of this greenhouse gas by more than 44 percent.

By comparing the climates of Earth, Venus, and Mars, I have considered the solar irradiation of these planets, the equilibrium temperatures that they would have without their atmospheres, and the temperatures that currently characterize their surfaces, due to the greenhouse gas warming produced by their atmospheres. Through these planetary comparisons, I conclude that warming by greenhouse gases has played an important role on all three planets. Moreover, the warming scales with the total amount of greenhouse gases in the respective atmospheres. By focusing on the carbon dioxide content, I have found a quantitative warming relation that scales with the 0.3 power of the carbon dioxide mass overlying each square meter of planetary surface (see Figure 1). This relation is consistent with the more recent warming experienced on Earth.

Although the atmospheric photochemistry that underlies the observed warming is complex, K-12 students can still progress in their learning – from basic observations of rising temperatures and carbon dioxide levels to plotting quantitative relations, interpreting their significance, and deliberating over possible human interventions. These remediations include decarbonizing our energy production, industrial processes, and modes of transportation, along with sequestering the excess carbon dioxide by cultivating more trees, kelp beds, and other natural photosynthesizers. A 30-minute video presentation on this subject is available at https://www.youtube.com/watch?v=nUqW8BGbcz0.

Astronomy Education and its Role in Saving the Environment

Presenter: Hassan Baghbani, Iranian Teachers Astronomy Union, Iran

Collaborators: Mahdi Rokni, Fatemeh Hasheminasab, Elham Rajaei, Ayda Rajaei, Mina Someilipour, Ameneh Jamali, Fatemeh Baghbani [1].

The role of astronomy education in helping to preserve the environment Bushehr Teachers' Astronomical Society has changed the way they look at the Earth by holding several astronomy courses for teachers and students in different cities of Bushehr province, so that instead of having a limited view, they can have a long-term view on preserving the environment. These trainings are the formation of the largest environmental protection groups in different cities of Bushehr province, which has been able to make the most successful examples of environmental protection in Iran.The way it works is that after training teachers, they build environmental conservation teams in schools and teach students, and make students' families more sensitive to environmental protection.

Poster link: https://astro4edu.org/siw/p22

ITAU is the first interdisciplinary teacher union of Iran with teachers from elementary, secondary and high school, who work in astronomy and nature fields simultaneously.

After many years of activities there are 20 active local groups of teachers and students in Bushehr and 9 more associations in other provinces of Iran. This association is busy with teaching the teachers and teacher-students, especially in underprivileged areas. Till now more than 2000 teachers have gained education in this field from this union. Also, about 10000 students annually participate in different activities and workshops in motivating the teachers and forming local and international teacher groups are some of the aims in different ways. Teaching astronomy and environment to the teachers of this union.

The result of proper training of teachers and their attention to environmental protection has led to the formation of the most important environmental defense movements in Bushehr province, in all of which it has been led and managed by teachers. For example, in 2016, prevented the establishment of a petrochemical plant in the middle of the abpaksh. Also in 2018 because resistance to the operation of a stone mine that caused the destruction of the Biramy Mountain and the water springs of the region was stopped, the leaders of that protest were teachers.

[1] www.skylian.org

One of the other efforts of teachers to preserve the environment is Resistance against the destruction of Avicenna forest and the rescue of Nayband National Park from a tourist town and hotel construction that is still underway. The result of six years of efforts by these groups. Preventing the establishment of a petrochemical plant in the grove ,Three large mines in environmentally sensitive areas And so on. ITAU tried to correct the views of society as much as possible. In the first step: training in teamwork and holding joint programs will create a close friendship between peoples. Training And preventing excessive consumption, especially of vital elements such as water, has an important role in preventing poverty and migration.

Accompanying the local community and protecting the environment and planting trees and protecting animals are a great help to the environment. Self-knowledge and better understanding of themselves in the form of team projects will improve students' view of future business.

Discussion summary

After the recorded talks, the session hosted a very lively round table with the speakers replying to the audience questions. Let me recap here some of the more interesting: "How can we get governments to act now and cooperatively across the world for long-term solutions?"; "How can we go from awareness to action? In case, what kind of actions would you suggest to citizens?"; "Do we astronomers have to rethink our social role? Do we need to spread more curiosity, inspiration, and motivation?"; "Are we doing enough? How to do more?".

While replying to those questions, the round table participants agreed that we astronomers have a relevant role in spreading the knowledge, in education. We astronomers can help advance the public understanding of global warming. However, we must share that knowledge with a positive attitude. And it is a matter of using the right approach and leveraging on our inspirational role. Also, we should share the same wonder that we felt as kids, pondering on the Universe. Those sensations inspired us, motivated us, and ultimately also defined what we are as grown-ups. Introducing early kids to the cosmic perspective may help have better, more aware persons in the coming years.

Equity, Diversity and Inclusion in Education

Session organiser: Stefania Varano,
INAF - National Institute for Astrophysics, OAE Center Italy, Italy

Session overview

Astronomy is always pinpointed as the "most fascinating of all sciences", the one with the greatest potential of interesting and involving enormous amounts of people, regardless of their age, culture, personal history, tastes, learning styles. Great power and opportunities, but also deep duties. Particularly the one of being aware of the huge diversity our world hosts, where no one is equal to another and where everybody should be given the free choice and opportunity to approach science and astronomy.

In this session, we tried to give specific suggestions and insights on how to deal with such diverse individuals and how to devote the power and charm of astronomy to enhance equity in access to scientific culture, and to foster diversity awareness.

During the session, Amelia Ortiz Gil presented Universal Design for Learning, Angela Perez offered a series of inspirational ideas for inclusive education in planetariums, Alan Alvez Brito suggested how astronomy can also foster interculturality, by enhancing self-awareness of cultural and social complexities, Keivan Stassun talked about neurodiversity in scientific learning contexts, and Angelica Minodora Nechifor presented effective student-centred approaches, such as project-based learning.

Universal Design for Learning in Astronomy Education

Speaker: Amelia Ortiz-Gil, University of Valencia Astronomical Observatory, Spain

The Universal Design for Learning (UDL) is an educational framework that relies on the individual abilities of each student to conduct a successful learning process. UDL is about breaking the barriers (physical, emotional, cognitive) that many students face, in particular those with a disability. In this talk, we will outline some general strategies to develop education resources in Astronomy following the UDL principles along with some examples.

Talk link: https://youtu.be/sWja71f04ec

Every day we have to deal with a lot of diversity in our classrooms. Each student is unique and has a unique learning style. Some can even be differently abled. But all of them also have unique learning strengths which are closely related to their unique learning styles. Therefore, to get the most out of them as students we need to take into account everyones' uniqueness. So the question is: how can we teach all this diversity together?

Universal Design for Learning (UDL)

The Universal Design for Learning is a framework that focuses on removing all kinds of barriers (which could be physical, sensorial, affective or cognitive) to gain access, learning and participation for students. This is even more clear in the case of students with special needs. The key is not to focus on the "disabled person" trying to change them, but rather on the "disabling environment".

UDL principles: The key to address diversity is multiplicity:

- Provide **multiple means of representation**: as different people perceive and understand the information in a different way, we must provide the contents through different perception channels. An example of an activity that follows this approach is the planetarium show "The Sky in your Hands", which combines visual, tactile and sound elements.

- Provide **multiple means for taking action and expression**: students differ in the ways in which they «navigate» through the learning environment and communicate their thoughts.

Give opportunities for taking action (through materials everyone can interact with) and opportunities for communication (through software and other means). Without these alternative means for communication and interaction, Prof. Stephen Hawking would have never made his extraordinary discoveries about the Universe.

- Provide **multiple means for engagement**: students differ in the ways in which they can feel engaged and motivated to learn. We can make use of broad choices that reflect the student's interests and provide them with strategies to deal with new contents/activities so they feel more confident. A good way to engage your students is by taking advantage of virtual reality technology, as is done in Chandra's project "Walking among the stars".

A UDL general protocol: A general protocol to follow when designing learning activities in UDL could be summarised by the following:

1. **Teach to all the senses**: There are as many different learning styles as learners. Everyone has his or her own way to learn. This is often usually linked to a particular sense: some students remember better what they see, others remember better what they hear, or some others what they touch, for example. Moreover, several research works have shown that we learn and remember better the information that we have acquired through more than one physical sense.

2. **Teach to strengths**: Use the natural abilities and talents as a foundation for learning or, in order words, focus on the abilities and not on the disabilities, if there are any.

3. **Provide multiple forms of feedback**: To find about your students' strengths, you need also to provide multiple forms of feedback to gather a complete picture of the students' abilities and to check whether the contents are being acquired correctly.

Specific actions

- Check with the students about their special learning needs. Take into account that if you help those who are in the extremes of the learning spectrum, you are also helping those in the middle.

- Make sure that the activities, resources and equipment are physically accessible to and usable by everybody. For example, reading aloud some written information while the students read it will help everybody to understand and remember it better, in particular those with reading problems, or the visually impaired.

- Provide a variety of means to deliver content, motivate and engage the students. This can be done through hands-on activities, collaborative learning, inquiry-based learning, educational software, internet-based communications.

- Make sure that the communication methods are accessible to all.

- Perform group activities in which students have to support one another by placing a high value on their different skills and capacities. This helps them a lot to build up their self-esteem.

- Ask for feedback from the students regularly and then adjust the activity accordingly, if needed.

- Plan for alternative accommodations for students whose learning needs are not met by the activity, for example, by providing materials under other formats.

Resources:

- US National Center in Universal Design for Learning (https://www.washington.edu/doit/national-center-universal-design-learning)

- Space Learning is for Everyone (https://www.nasa.gov/stem-ed-resources/Space_Science_Is_for_Everyone.html)

- The Sky in your Hands / A Touch of the Universe (https://astrokit.uv.es)

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Astronomy and Education, with Planetarium Eyes

Speaker: Angela Patricia Pérez Henao, NAEC Colombia, Planetarium of Medellín, Colombia

To understand how to contribute with strategies and activities for students and the general public in astronomical observatories and planetariums that constantly receive diverse audiences, from the IAU's motor disability group we conducted a survey that would allow us to understand this situation. We will present the results that we have so far and the conclusions and contributions that we have.

Talk link: https://youtu.be/_ST1VWqRt7A

For several years the need for city spaces or places that welcome all types of audiences without distinction has been on the rise. In order to strengthen the processes and experiences of inclusion and equity in the institutions with which I have the opportunity to interact, schools and planetariums, and to contribute to a more inclusive society, I have been involved in the development of accessible itinerant educational material. I am part of a working group of the IAU that seeks to understand the real situation of the Planetariums to receive visitors, among these students, with special mobility capacities.

From the previous perspective, it is irrefutable that the protection and enjoyment of the rights of people with disabilities can be given from the presence and interaction in different spaces, in this case cultural, that enable comprehensive training through the elimination or reduction of physical and social barriers. In this sense, spaces such as the museum have been thinking about their accessibility for people with disabilities, trying to eliminate architectural barriers, favoring access to information, adapting galleries and/or museum collections, among others.

First approach: We focus our efforts on raising awareness in the population about the cultural needs of people with disabilities. Hence, we developed the Astronomy suitcase with all the senses, a proposal that was born from the interest of two teachers and myself, to awaken the interest in astronomy topics, to blind students from some educational institutions in the city of Bogotá. This project in the first place with volunteering and the firm purpose of expanding the opportunities of blind children as well as providing new teaching tools to their teachers.

The strategy was well received by the target audience and it surprised us, as it also became a training tool for teachers on accessibility issues, a tool that raises awareness in students, teachers and the general public to understand that we all have the same right of access to the information. Thanks to the support of the OAD, this material exists in Colombia and Chile, with the possibility of free replication to those who wish to copy it.

With this material we understood that access to information on astronomy issues should also be extended, with this methodology, to neurotypical people, and even cognitive disabilities and reduced mobility. The use of 3D models, which can be easily manipulated, allows the experience of knowledge to pass through the body. This becomes beneficial for all types of people.

Second approach: With the working group on physical disability of the International Astronomical Union, three people in different contexts (UK, USA, and COL), we want to better understand how the accessibility situation is in Planetariums. We want to analyze, gather references and produce written, audiovisual, sound material that facilitates the approach or learning of astronomy to people with physical disabilities.

The strategy was well received by the target audience and it surprised us, as it also became a training tool for teachers on accessibility issues, a tool that sensitizes students, teachers, and the general public to understand that we all have the same right of access to the information. Thanks to the support of the OAD, this material exists in Colombia and Chile, with the possibility of free replication to those who wish to copy it.

On the other hand, the deepening of the universal design created mainly to generate spaces for everyone can be extrapolated for use in the development of strategies beyond the infrastructure, as it can inspire in the processes of content design, teaching material, activities, and strategies for teaching and disseminating science.

Contribution in education: From my perspective as a disseminator and teacher trainer in didactics of astronomy, I have found that the generation of the material in the Astronomy

Evaluation of prototypes with blind students.

suitcase with all the Senses and the incipient findings of the survey on disability in planetariums, with the view of the use of spaces. It makes me think that the Planetarium and the School have a lot to share as educational and/or outreach spaces.

In this sense, the teaching and learning strategies of both spaces complement each other, especially from the Planetarium to the School.

Resources:

- http://astrokit.uv.es/
- http://materialdidacticoparaciegos.blogspot.com/2013/10/el-sol-tactil.html
- http://science.nasa.gov/science-news/science-at-nasa/2008/15jan_touch/
- Photographic record 2006 – 2014 Angela Pérez
- Photographic record Nayive Rodríguez
- Inclusión working group: https://iau-oao.nao.ac.jp/iau-inclusion/motor-impairments-2/
- Questionnaire for planetariums: https://docs.google.com/forms/d/e/1FAIpQLSdw7x9Z1QiInyELCoZ5u67g269vh8NQhg3ArmMvWOTasdM8TQ/viewform

Interculturality and Ethnic-racial Relations in Astronomy Education and Communication

Speaker: Alan Alves-Brito, Institute of Physics - Federal University of Rio Grande do Sul, Brazil

Focusing on Astronomy, I will address some key aspects related to the main challenges and potentials of the science education and communication platforms for the promotion of social justice, equity, diversity and inclusion in Brazil, disentangling not only ethnic-racial and gender issues, but also historical and philosophical elements of science. I will show some ongoing projects, discussing their methodologies and main outcomes.

Talk link: `https://youtu.be/IRdunCbN7pI`

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First, I present the situation in Brazil from the ethical-racial perspective, showing some numbers that reveal Brazil's daily structural, epistemic and symbolic racism toward black and indigenous people. The remarkable reality is that even though 56% of the Brazilian population is self-declared black, the great majority have no access to (quality) education and scientific culture. At the University system, black/indigenous people are underrepresented, with only 10% of the professors/scientists accounting for black people. In this context, Intercultural Astronomy is considered as a strong tool in Brazil to benefit society and trigger development, as since 1988 different education laws/documents have been approved, which acknowledge that black and indigenous people are citizens, requiring the mandatory treatment of the history, culture and contribution of African, Afro-Brazilian and Indigenous people to science and Brazilian life at all levels of the education system.

Second, I present three main educational/communication projects focused on Intercultural Astronomy that we have been developing since 2017: (i) Akotirene Kilombo Ciência that is focused on the empowerment of black girls/boys specifically from Maroon (quilombola) origin; (ii) OruMbya (Orum, sky in Yorubá, and Mbya, a Brazilian Guarani ethnicity) is a pilot project to celebrate Astronomy as the fuel of life, in which the stories of the stars are preserved in the resilience of people from four different continents and shared over months, through scientific-cultural activities focused on the dissemination of knowledge, promotion of social inclusion and sustainable development in the context of PLOAD (Portuguese Language Office of Astronomy for Development); and (iii) Zumbi-Dandara dos Palmares Project, which is an action-research project focused upon developing a complete diagnostic of the quilombola's education in Brazil and, at the same time, offering workshops on artificial intelligence, digital skills and the development of computational thinking for black girls/boys, everything mediated by Astronomy tools as well.

Third, I will mention the main theoretical and methodological references we have been using to date. We have used a decolonization approach, as well as the participant-ethnographic perspective, being together with black and indigenous communities all the time, listening to them and helping them in their political movements for a better life, that is, education combined with other aspects of their lives. We have been taking the black and indigenous people's thoughts and insights into account on different aspects of their alterities. As a rule, being together with people, listening to them and exchanging ideas and cosmic perceptions, has been crucial to the success of our projects. In order to do this, Inter-Cultural Astronomy has been our main theoretical and methodological umbrella, as different narratives on phenomena that happen or are present in the sky have driven us away from the colonial way of thinking and interpreting reality.

Fourth, I mention some of our main results, which are, from the University's point of view, related to a better training of our undergraduate students, as well as building new ways of thinking about history and philosophy of science, epistemology, psychology, language, politics and culture. I discuss how the historical construction of the contemporary concept of science, technology, development, innovation and meritocracy needs to be changed, to help us answer fundamental questions: why are there so few black people in Physics and Astronomy in a mostly black country? Are these areas of knowledge "affirmative actions" for whites? Why does scientific racism, a pseudoscience, not have the same status (concern) in science education and dissemination programs in Physics and Astronomy? I conclude by pointing out that science and its methodologies are human constructions indissociable in its historical, social and political dimension and, thus, the social markers of difference (subject versus object) in science and science education and communication need to be considered in the whole process of face-to-face contact with people. This attitude is crucial in order to allow us to rethink our power relations in science at school, university and society, decolonizing our thoughts and building positive models based on the black and indigenous identities, promoting the urgent racial equity in Brazil.

Supporting Neurodiverse Learners for Research Experiences in Astronomy

Speaker: Keivan G. Stassun, Vanderbilt University Frist Center for Autism & Innovation, USA

We describe the activities and lessons learned from a physics and astronomy research internship program operated by the Frist Center for Autism and Innovation at Vanderbilt University. The program is intended to engage and support neurodiverse learners in research experiences that prepare them for success in university, graduate school, and future research careers. We describe the program goals, outcomes, and tools that have been developed for use by others seeking to increase the participation and success of neurodiverse individuals in astronomy careers.

Talk link: https://youtu.be/h9ySVyu5-kg

As a way of introducing neurodiversity in the context of astronomy research and discovery, we present the example of the discovery of stellar granulation "flicker", originally published in Nature by Bastien et al. (2013). That discovery—which has advanced the ability to accurately characterize the sizes and ages of stars, and therefore of exoplanets orbiting those stars—was made by a team of faculty and students at Vanderbilt using a novel data visualization tool called Filtergraph, which was invented by an autistic researcher on the team (see Burger et al. 2013). The complete story of the invention of this tool and of the astronomical discoveries that resulted was recently highlighted in the television news show 60 Minutes with the American journalist Anderson Cooper (see https://www.youtube.com/watch?v=YnAUy4BM0w8).

Supporting Neurodiverse Students: COVID and Beyond

It is important that as a community we learn how to best mentor and support our students. The past year of COVID has forced us to learn to support all of our students in new ways. During normal times, at the Frist Center we run a research internship program in person, with on-site coaches for social skills (Figure 1). We also have launched an interdisciplinary PhD program that we call Neurodiversity Inspired Science and Engineering, through which graduate students – both neurodiverse and neurotypical – pursue research projects that lead to innovations to support and/or are inspired by neurodiversity. In addition, we have partnered with major international companies, such as Ernst & Young to place our interns into great jobs after graduation, for those who wish to take their astronomy training into the private or corporate sector.

During Covid, we had to implement some new types of supports as everyone worked in remote or hybrid environments. These include regular check-ins on zoom with a coach to discuss progress, get advice on managing time and workloads, and mental health. A social worker

Figure 1: Neurodiverse research interns at Vanderbilt's Frist Center for Autism & Innovation, shown with on-site coach at far right. Credit: Vanderbilt University.

Figure 2: Screenshot of the free online resource developed by the Frist Center for Autism & Innovation to assist autistic and other neurodiverse teens and adults set and pursue self-determined goals. Available at triad.vkclearning.org.

has been available as needed for emotional and psychological support. We also have used the challenges of the Covid experience to elevate autistic voices and to develop new tools.

For example, we started a monthly webinar series featuring our autistic staff and interns, discussing the challenges of Covid and of neurodiversity from a global perspective including autistic researchers from around the world. These discussions proved so valuable for building a global community, that we are continuing them even after Covid.

Finally, we have used our experience to create an online self-guided tool for learning how to set and pursue goals that autistic and other neurodiverse people can use for their own professional development (Figure 2). It is available at the web address: triad.vkclearning.org.

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Astronomy and Inclusive Education through Project Based Learning

Speaker: Angelica Minodora Nechifor, CYGNUS Scientific Society, Romania

Project based learning and inclusive education is a way to promote Astronomy Education, STEAM subjects, to develop skills: critical thinking, problem solving or inter and transdisciplinary approach communication. Teachers and students from all over the country, or world, can work together, supervised by teachers for Sciences, Astronomy, and astronomers by Science, Technology, Arts and Mathematics activities. We would like to present you the way we can teach astronomy using practical and attractive, non-formal methods, linked to outdoor education and CLIL. It is innovative and creative. Children from primary schools can work with secondary and high school students to ensure peer and collaboration learning. In August, we will organise a conference and we wish to present also its results.

Talk link: https://youtu.be/yuAuan_ZHyA

Project based learning and inclusive education is a way to promote Astronomy Education, STEAM subjects, to develop skills: critical thinking, problem solving or inter- and transdisciplinary approach communication. Teachers and students from all over the country, or world, can work together, supervised by teachers for Sciences, Astronomy, and astronomers by Science, Technology, Arts and Mathematics activities. We would like to present to you the way we can teach astronomy using practical and attractive, non-formal methods, linked to outdoor education and CLIL. It is innovative and creative.

I am a teacher in a mainstream school, but at the same time an inclusive one, situated in a beautiful mountain area, but, unfortunately, in a former mono-industrial town.

Since 2006, when the copper mine closed, there are no jobs for people living here; therefore, many of our students' parents left to find jobs in other countries. Our students come from different environments, with very diverse backgrounds. Most of our students are Romanian, but some are Hungarian, or from mixed families, some are Romas. Their parents and grandparents came years ago from different parts of the country to work in the copper mine, so they are very diverse in culture too. Being a multi-ethnic, cultural and religious community made us appreciate diversity; it is useful for each community member's tolerance, empathy and assertiveness.

However, there are many problems due to the poor family background of some of our students or to their psychological and emotional state. We have at least one special education needs child in each class, meaning students with autism, ADHD, Down syndrome, dyslexia and dyscalculia, intellectual disability. We even have students with visual and hearing impairments, to different degrees. What most concerns us is that many of them are not diagnosed and this challenges us to use integrated and inclusive teaching methods to make sure that each child in our school is valued and motivated to learn. With these children, we work with an adapted curriculum for their needs. We do encounter problems, but we try to cope and show them attention. In terms of Astronomy, we can only teach easy things and this is why we want to implement the "RO300 Stars" project, or "Wandering through the Universe, We Aim to the Stars"

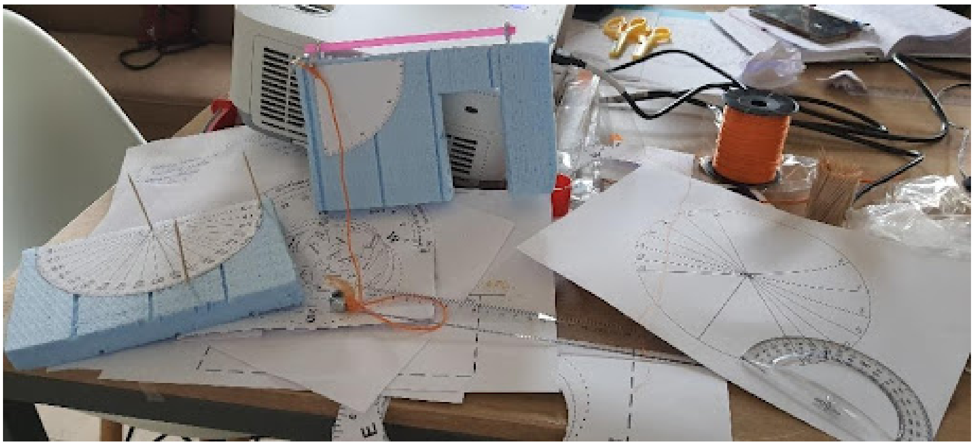
This project is about promoting educational activities related to the field of Astronomy and Space Sciences with a view to a future STEAM professional career, as well as to sharing and using examples of good practice for sustainable development (clean energy, solutions for the climate change etc.) at local/ national/ global level.

It involves students aged between 6 and 11 years old (divided into two categories: aged 6-8 and 9-11), with different backgrounds: students from mass schools, including those being in risk situations, such as learning difficulties or even Special Educational Needs, severe disabilities, like blindness, under-privileged group belonging, minorities, difficult family situations.

An example of PBL is one of the activities in the We aim to the Stars Workshops (WSW) **"Guides for teaching Astronomy to primary classes"**, namely **"How to land on the Moon or Mars?"**.

Children work in teams, with specific roles, with names. They have to build a spaceship that will take the astronaut – an egg – safely to the moon. They have to "go" to a shop and buy things they need to build their ship. They have to undergo a fixed budget, so entrepreneurial skills are developed. When they have everything they need, they start to design their ship, drawing it on a scale, and so these little engineers can exercise their planning, counting and technical drawing skills. Then they move to the practical part of this activity and build their ship in which "the astronaut" will be set for its mission to the Moon. Finally, all the spaceships are launched and if the astronaut lands safely, meaning the egg is safe and entire, they are declared space engineers. As children are attracted to rewards, we can even design some ID cards or badges using different apps such as Canva. I think it is obvious how many skills we can develop with an activity like this: entrepreneurial, mathematical, design, communication, collaboration and so on. If we ask them to send a message into space in a foreign language, we can even develop linguistic skills. Each child, even the special needs ones, can find something interesting in working in this kind of activity.

In order to cope with the needs of this pandemic situation, we can use many applications to help students work together, even if they will not be able to meet. One I have already worked with is Action bound, an application for smartphones and tablets that helps the participants to accomplish a mission. Teachers need to create an account in order to create the challenges for the bound and we can use it for different treasure hunts, missions or games. Participants can participate on their own or, more important for us, in groups. Challenges can be played outdoors or online, depending on what we want to achieve, on our imagination and on the proposed challenges. We used it for a local treasure hunt this August 2021, but we should let our imagination fly and create bounds connected to what we like or to our students' interests. It is more than important to understand that nowadays students are different from former generations, that we need to be creative to catch their interest. Information is now at one-click distance, they do not need teachers anymore to "inform" them, but to guide them. The future successful teachers will be those who will be able to find each individual's needs and to guide them until they find their way, whichever that is.



Instruments built by children

Working together on the spaceship in the activity "How to Land on the Moon or Mars?"

Final product and launching the spaceship

The Past, Present and Future of Earth and Space Education, and Implication for Equity

Presenter: Christine Hirst Bernhardt, University of California, Santa Barbara, Endeavor STEM Teaching Project, USA

Astronomy education, particularly in Western Nations, has the potential to disrupt colonial narratives while providing greater access to 21st century skills. Participants will be provided a space to explore the integrations of astronomy to foster and facilitate equity and justice, while connecting to the natural world. Some issues may be personally challenging to address, such as environmental racism and bias. This session will be highly interactive and allow participants to explore the use of satellite imagery to address social justice issues in their region and abroad. Participants will develop their own activities connected to their individual spaces which they can immediately use in formal K-12 education settings.

Poster link: https://youtu.be/5zYEirg9Z0w

This session will explore astronomy education as a tool of equity while equipping educators with the tools to build bridges between student experience and the natural world through a social justice lens.

Earth and Space sciences encompass the most neglected realm of science education in the United States, as well as the lowest representation of Women and People of Color. For over a century, high school science coursework has minimally included biology, chemistry and physics, integrating Earth sciences in middle grades and eliminating astronomy. There has been no national test, curricula or standardization for astronomy coursework. The scarcity of course offerings and absence of Advanced Placement or IB courses have relegated coursework to university settings, by which time the moment to select a STEM field has likely passed. Secondary and primary environments are critical for the formation of a STEM identity, particularly amongst girls and students of non-dominant groups. This session will explore the integration of space sciences in formal education settings to foster STEM identities and build bridges between science, community, and the classroom. Utilization of the space environment can unify learning from other contents, while providing opportunities to explore the evidential sources of knowledge of our world. The United States is currently at a pivotal crossroads in science education; the recent inclusion of Earth and Space content into newly adopted national standards, particularly in earlier grades, provides a unique opportunity to contextualize science learning. This is especially important following a year of remote learning, and more so for students in urban environments. In 2013, the National Research Council adopted the Next Generation Science Standards (NGSS), which identified and assigned equal weight to the content areas of life (biology), physical (chemistry and physics) and Earth and Space. This is a stark difference from the previous 100 years of education, and allows for a drastic restructuring of science course sequencing. There is now a far greater emphasis on Earth-Space systems across all grade levels, reflecting the interdisciplinary nature of the field. The exposure to meaningful and relevant science activities can provide an inclusive environment to traditionally marginalized students who do not see the real world applicability of science in their lives.

This session will explore astronomy education as a tool of equity. Students in urbanized settings may have even less academic exposure to astronomy and space sciences through a vicious cycle of deficit thinking and systematic oppression. A pedagogy of poverty has been the dominant narrative in which high teacher turnover in urban schools fosters a reliance on curricularizing [science] coursework to a minimum set of knowledge requirements, which remove connection and application to local context and settings. In urban schools, this curicularization may look like non-local examples, unrelatable representation, and a failure to incorporate areas of relevancy and urgency from daily life into the classroom. This can further complicate the incorporation of space sciences, which may seem abstract, complicated, and unnecessary. One can only imagine the magnification of this separation following a year of remote, removed learning mediated by a screen. By providing mechanisms of access to space sciences connected to local environments, educators can facilitate authentic learning experiences to previously excluded students in these fields.

Astronomy education, particularly in Western Nations, has the potential to disrupt colonial narratives while providing greater access to 21st century skills. Participants will be provided a space to explore the integrations of astronomy to foster and facilitate equity and justice, while connecting to the natural world. Some issues may be personally challenging to address, such as environmental racism and bias. This session will be highly interactive and allow participants to explore the use of satellite imagery to address social justice issues in their region and abroad. Participants will develop their own activities connected to their individual spaces which they can immediately use in formal K-12 education settings.

The Urgency and Contribution of the Planetarium in the Development of Astronomy in Rural Areas

Presenter: Muchammad Toyib, Surabaya Astronomy Club, East Java Amateur Astronomer Communication Forum (FOKALIS JATIM), Indonesia

A planetarium is a theatre built primarily for presenting educational and entertaining shows about astronomy and the night sky, or for training in celestial navigation. The position of the planetarium in an archipelagic country like Indonesia is very important, especially for people in rural areas to get equal rights in obtaining education and access to technology. With a planetarium that is easily accessible, it certainly allows the public to observe celestial objects together and gradually get scientific information to bring them closer to science, especially astronomy, using fun, interesting, and engaging activities. Through this process, the existence of a planetarium has become a potential tool for community building in various regions and even rural areas in Indonesia.

Poster link: https://astro4edu.org/siw/p47

Over time, human civilization has been progressing. We have successfully launched artificial satellites for decades, humans have even been able to walk on the surface of the moon, set up the International Space Station, send probes to other planets, and most recently, we are still trying to uncover the possibility of other habitations beyond there. On the other hand, although we often hear about some of these achievements through the media, few of us have in-depth knowledge of celestial objects, or simply about the Earth we live on. In fact, we hardly care about any of these things.

The planetarium is not only a means to acquire astronomical knowledge but is also a valuable medium to increase people's awareness and love for this one and only habitable planet. Planetariums can give the impression of the infinity, dignity, regularity, and wonder of the cosmos and inspire our minds to explore so many other fields of science. Planetariums can also provide an escape from the stress of everyday life. Relaxing under the serene starry sky brings peace and creativity back to the overworked mind. Lastly, the planetarium functions as a science center, where the public has access to the latest news about the current scientific happenings, as well as a place for a scientific discussion about the universe.

Above all, planetariums benefit our minds and souls as social beings. They can give great power to imagination and stimulate creativity in future generations, which will shape the future of our civilization. In this way, building a planetarium brings countless rewards. The development of planetariums in various regions can be a positive paradigm, which will cancel the dichotomy of access to education that often occurs between those who live in urban areas and those who live in villages or even rural areas.

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Teaching Astronomy with Culturally Responsive Citizen Science Curricula

Presenter: Christine O'Donnell, Arizona State University, USA

Collaborators: Molly Simon and Peter Smith (Arizona State University)

We are developing culturally responsive curricular materials based on Zooniverse projects for general-education college courses. The Zooniverse is the largest online citizen science platform; since launching in 2007, it has supported over 200 projects and connected researchers with over 2 million volunteers worldwide. Our curricular materials improve the teaching and learning of astronomy by guiding students to contribute to ongoing research projects and by empowering students to connect content with their own lived experiences. Students will also practice critical reflection skills and engage in scaffolded dialog about equity and inclusion in astronomy and space exploration. These materials will undergo extensive pilot testing beginning in Fall 2021 before being made publicly available.

Poster link: https://youtu.be/ouRZg0CalCE

In the US, hundreds of thousands of college students take general education science courses each year. These courses are designed for non-science majors to contribute to their broad set of skills and knowledge for their future lives and careers as policymakers, business leaders, voters, teachers, parents, etc., but these courses also often represent the last formal exposure to science that these individuals will have.

From previous education research [1-2], we know that general education science courses struggle to foster both a sense of self-efficacy (i.e., the feeling that one is capable of engaging in science) and a sense of belonging. However, research also illustrates strategies that can be used to address each of these challenges. For example, curricular materials that have students participate in citizen science efforts, which are projects designed to engage the public in the process of scientific discovery by making real and valuable contributions, can increase students' self-efficacy [3]. Additionally, culturally responsive approaches that connect students' own knowledge and beliefs with content, promote reflection, and foster peer connections and community can encourage students to feel a sense of belonging [4].

In this work, we aim to create a new framework for curricular activities (intended for two 50-75 minute class sessions with homework in between) that are built on a culturally responsive foundation and engage students in ongoing citizen science research projects to improve the teaching and learning of astronomy. Our materials feature projects from the Zooniverse, the largest online citizen science platform; since its launch in 2007, it has supported over 200 projects and connected researchers with over 2 million volunteers worldwide. Specifically, we have students who take part in the Planet Four project [5], which has volunteers identify and classify features on the Martian surface to learn about the weather and climate of Mars. Throughout the activities, students will learn about why researchers study Mars and how their work might benefit people on Earth. Before engaging with Planet Four, students are asked about their current notions of what it means to "do science," and after contributing to the Planet Four research project, we ask students to reflect on their experiences and to compare with their prior beliefs about "doing science". Next, students will have options for completing a deeper investigation into the study and exploration of Mars that aligns with their own personal interests. They will have opportunities to share their findings with their peers to foster peer connections and community. Finally, students will work in small groups to engage in a discussion on current topics and policy debates, such as planetary protection. These materials are currently undergoing an extensive pilot-testing at a range of different institutions (including R1 universities, liberal arts colleges, and community colleges) before being made publicly available.

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Cazadoras de Estrellas: Reduce the Gender Gap in STEM

Presenter: Victoria Paz Perez Gonzalez, Universidad de Chile, Chile

Cazadoras de Estrellas is an astronomy course for Chilean high school girls, founded in 2018 by female astronomy grad student at the U.Chile. In this course, the girls learn about the astronomy career, programming in Python, and most importantly, the role of women in Astronomy. We include specific moments to talk with them about women in science. We want them to know about our own journeys as astronomy students, and question their own interests and experiences. In this presentation we want to share the importance of an explicit approach to gender problems in Astronomy Education, giving young women space to reflect about this and meet with young female scientists, helping them identify the main problems that women still face when deciding to be scientists.

Poster link: https://astro4edu.org/siw/p50

Historically women were not included in academic institutions, resulting nowadays in a lack of feminine role models and STEM fields being considered as "masculine". In Chile, overall women's university enrollment is around 54%, but for STEM careers it goes down to 22,6% (CONICYT, 2018). Additionally, female participation decreases to 10% at an academic level. As a group of female astronomy grad students at the University of Chile, this problem worries us and makes us want to propose a solution for it.

Cazadoras de Estrellas project founded in 2018 that consists of a series of courses that teach Astronomy to Chilean high-school girls, with more than 850 applicants and 450 participants to date. We offer a course in Astronomy, in which the girls learn about Variable Stars as a central topic. Through that, they learn about the history of Women in Astronomy, the Astronomy career in Chile, programming in Python, and most importantly, the contemporary role of women in Science. *Cazadoras de Estrellas* has visited 6 regions in Chile during 2018 and 8 more during 2020-2021. For the second round of courses we have been able to take this experience to interested girls, and also develop a research on women in science based on our participants, where we are interested in knowing more about gender stereotypes that our female students deal with in different territories inside our country.

Our courses include specific moments of open discussion about gender issues in science. We want them to know about our own journeys as astronomy students, and question their own experiences. Originally, the course was designed as a 2-day classroom course, but due to the COVID19 pandemic, we had to adapt our plan and transform it into a complete online experience that would last two weeks, just for the pandemic epoch.

In this poster presentation, we share our experience teaching these courses and also communicate the importance of treating gender issues with girls. A key part of our course consists in giving young women the space to talk and think about this, through open discussions with us, young female scientists. We share our academic and personal paths as women to newer generations, and through this experience, we identify the main problems that women still face when deciding to continue scientific careers nowadays, female students still have to deal with a lot of barriers in comparison with men. Gender bias still is an obstacle for young women to enter STEM fields.

Our experience with *Cazadoras de Estrellas* has shown us that it is important to highlight female role models to young women. Role models and safe spaces can help bridge the gender gap in science. After the workshop, girls feel more empowered and self-confident as they wrote in the closing questionnaires.

Discussion summary

The main aim of the session was to encourage diversity awareness and to support designing processes that aspire at granting everyone the opportunity and free choice to access scientific culture. Not only, we tried to figure out to what extent astronomy, also thanks to its universality, charm and fascinating power, can be a means to add something to this framework, and how we can use it to foster everybody's self-esteem and self-confidence with regards to science, but also life in general and not to self-exclude by activities they feel are not "for them".

One of the main issues we discussed at the end of the session was if and why Astronomy can be a privileged way of access and pursue equity goals. Some of the issues with regards to that were: how Astronomy has a special appeal that helps the teachers, astronomers to translate it in something understandable for everyone, also addressing other disciplines; how Astronomy is made by very diverse groups within large international collaborations, helping fostering equity between the different countries and different cultures; how Astronomy is a human science in the first place, making it effective for reminding everybody that they have the right to be part of the game, bringing their own cultural, social and historical narratives on the table. Finally, Astronomy allows us to think about the past, present, future, who we are, why we are here, so philosophical questions are also playing a big part in the self- and diversity awareness process.

Evaluation of Resources and Activities

Session organiser: Silvia Casu, INAF -
National Institute for Astrophysics,
OAE Center Italy, Italy

Session overview

Evaluation is a very important topic when talking about education. Evaluation is a continuous process that critically examines a program; it can improve program design and implementation, assess its achievements and improve upon its effectiveness. It helps teachers and learners to improve teaching and learning processes. Evaluation helps us to make evidence-based decisions.

There are **different types of evaluation**, depending on evaluation purposes. There are evaluation activities that you conduct before you start your work and as you are planning (Front-end evaluation), while a project is in development (Formative evaluation), and at the conclusion of the program implementation (Summative or Impact evaluation).

There are **different types of data** you can collect to perform evaluation: quantitative data (numbers such as simple counts or percentage) and qualitative data (more descriptive in nature). Therefore, there are **different types of methods and tools** one can use to collect and analyse data, to understand *what* is happening and *why*: graphs, closed-ended surveys, checklists, rubrics but also interviews, focus groups, open-ended surveys and more interactive data collection methods. Moreover, we could use mixed methods in order to have a more holistic view.

This session aims to give a general and basic overview of types, methods and tools commonly used in evaluation, together with a list of open resources, to help teachers but also scientists and educators to plan the best assessment of their work.

An Introduction to Evaluation for Astronomy Education Programs

Speaker: Sanlyn Buxner, Planetary Science Institute and University of Arizona, USA

Evaluation plays an important role in developing and revising astronomy education programs and activities as well as understanding the short and long-term impacts on students, teachers, and members of the public. This presentation will give an overview of different types of evaluation including internal and external evaluation as well as needs assessment, formative, and summative evaluation. We will cover the difference between different types of assessments used in evaluation and how these types of data can be used to gain valuable information about your astronomy education activities. We will provide resources for assessment and discuss the difference between astronomy education research and evaluation. Lastly, we will provide resources for getting started doing evaluation.

Talk link: https://youtu.be/vmIo85aXJ3A

Evaluation plays an important role in developing and revising astronomy education programs and activities as well as understanding the short and long-term impacts on students, teachers, and members of the public. In general, assessment is important in helping us, as scientists and educators, make evidence-based decisions. Assessment helps us understand the needs of our audiences and our communities, understand the quality of our products and activities, and understand the alignment of our programs and activities to audience needs. Additionally, assessment helps us gather information to improve our programs and understand their impact.

I encourage everyone to evaluate their programs, big or small. If you do not evaluate your activities and programs, how will you know you have been successful? You use evaluation to figure out what you are doing well and what you can still improve. Lastly, you can use evaluation to convince others to give you time, money, and other resources.

According to the American Evaluation Association (https://www.eval.org/), program evaluation answers questions like: *To what extent does the program achieve its goals? How can it be improved? Should it continue? Are the results worth what the program costs? What are the long-term impacts? A program evaluation has to be designed to be appropriate for the specific program being evaluated.*

There are different types of evaluation that are important in any discussion about evaluation. There are evaluation activities that you conduct before you start your work and as you are planning, activities that you conduct during your work as you implement activities that will inform changes, and activities that you carry out at the conclusion of the program implementation. Below is an overview of the main types of evaluation.

Front end evaluation is conducted at the beginning of the project, often before you apply for funding. This may include a needs assessment where you get input from the audience or community you want or plan to work with. This is important as it tells you the types of things your audience needs or wants and avoids having you produce a program or activity that will not have an appropriate audience. This also helps you build trust and a roadmap about what you want to achieve. You may also consider doing a literature review of either peer reviewed literature, evaluation reports, or other reports that will inform your work. Lastly, reviewing other projects may give you important insight for your new program.

Formative evaluation is conducted while you are implementing a program. This type of evaluation helps you understand the quality of the implementation of your program. If you are running a short event, this may be just asking how things are going and what things can make it better in real time. If you have a multiple-day workshop, this may include some end-of-day questions to improve the experience for the next day. Formative can be an individual activity or for big chunks of your program. The most important aspect is that you want to collect data that is actionable. You also must be willing and able to make changes to your program. Collecting this data and making changes can demonstrate that you are being responsive based on feedback through an iterative feedback cycle.

Summative evaluation is conducted at the end of a project, or a piece of a project, to understand the impacts of the project. This is sometimes referred to as outcomes evaluation or impact evaluation. The overall purpose of summative evaluation is to report on the impact of your program on the intended audience and understand how engaging in your program or activity has had value for the audience. The summative evaluation is often what is shared in a report with your funding agency and can help you answer more long-term impacts about your program. When we think about the actual outcomes we are interested in, it is often helpful to think about the categories of outcomes. These might include participant knowledge, skills, achievement, interests, beliefs, motivations, attitudes, behaviors and choices. A nice framework for thinking about different categories of impact comes from the National Science Foundation Informal Science Education program document (http://www.Informalscience.org/framework-evaluating-impacts-informal-science-education-projects).

When we think about participant knowledge skills, and achievement there are a variety of ways we can measure these. These include using tests, grades on assignments on classes, concept inventories (specific surveys that are designed to get deep insight into students' knowledge about a specific topic), knowledge surveys, as well as interviews and focus group interviews of either participants or their instructors or supervisors. We can also review students' work in class, portfolios of their work or even make observations of performance-based tasks. If we are curious about participants' interests, beliefs, motivations, or attitudes, using surveys of interviews and focus groups will be the easiest way to gather information. If we are interested in looking at behavior and choices, we may choose to conduct follow up surveys or interviews of focus group interviews, or we may choose to look at records of behavior such as school and employment records. It is important to note that any tool you use should be for the data you want to gather so that it accurately asks what you are interested in. As you are thinking through the types of data you want to collect, it is important to ask, "How will I know that I have achieved my goals?" Once you decide on the types of data you want to collect, you will want to think about a threshold for success? Do you want to make sure everyone has a certain amount of knowledge that there is an increase? These questions both drive what you collect but also how you analyze data.

It is also important to think about whether we want to measure participants' knowledge, interest or motivations at one point in time, if we want to be able to show changes, or if we want to make claims about long-term impact. These types of decisions will tell us if we need to have a single survey (one point in time) or a pre- and post survey to show changes over time. If we want to make claims about changes in participants' knowledge or attitudes, we need to make sure to take a baseline (pre-) before the program so that we can feel confident that there was a change as assessed on the post survey.

There are two broad types of data that we talk about in evaluation. Quantitative data is data to which we assign a numerical score or ask participants to assign a value to something. Examples of quantitative data may include test scores, agreement scales (to what extent do you agree with), basic descriptive statistics (how many people chose this session). Qualitative data is descriptive data that is often in participants' words. Examples of qualitative data include open ended survey responses, essays, observation notes, and interviews. Qualitative data help us make sense of quantitative data and give us more information. It is important to remember that any type of data can be quantified including interview data (e.g. word counts). Each type of data lends itself to different types of questions and in evaluation, I often encourage folks to use both types of data to support different types of evaluation questions. One example of using both might be to conduct a large (1,000) quantitative survey of student knowledge about knowledge of Solar System exploration, interest in STEM, and career plans. Additionally, you might collect qualitative data through interviews of 20 students to better understand their survey responses, get more information about their interest responses (why they rated questions a certain way) and ask more deeply about career plans.

When we think about the difference between evaluation and research, it is important to remember that they are similar in data collection and analysis, but different in their overall purpose. Research is about understanding phenomena and generalizing, and evaluation is about making judgement about the value of your program. There is a nice discussion on `https://www.betterevaluation.org/en/blog/framing_the_difference_between_research_and_evaluation`.

Evaluation may include both internal and external evaluation. Internal evaluation often involves someone who is close to the project, who works on the project, and who may be invested in the project. Internal evaluators are often less expensive and faster in feedback. External evaluation involves someone who is not associated with the project, who is outside the power structure of the project, who can give a different perspective and honest feedback without a close connection. External evaluation is often more time-consuming and more expensive. External evaluators are often required by funding agencies. The overall take-home message is that evaluation helps you show the value of your work, gives you important feedback to improve and can be done on a small or large scale. Additionally, evaluation can be done by anyone! You can review your own programs, or help out a colleague. When looking for an evaluator, there are online tools such as the "find an evaluator tool" (`https://my.eval.org/find-an-evaluator`) of the American Evaluation Association university teaching and learning centers, dedicated evaluation centers at different institutes, your colleagues, other projects who have evaluators, and your network here.

I have put together a list of resources (`https://tinyurl.com/4stxyhf2`) that include guides to conducting evaluation, guides to preparing evaluation proposals and pieces of evaluation in proposals for funding, links to data collection tools including surveys, interview protocols, observation protocols, and rubrics for assessing work, resources for quantitative and qualitative analysis, sources of evaluation reports, and links to standards for evaluation.

Evaluation Basics: Planning for Improvement and Measuring Impact

Speaker: Amy Grack Nelson, Science Museum of Minnesota, USA

Evaluation is an important tool for improving astronomy education projects and assessing their impact. So how do you go about carrying out an evaluation? Learn about the key components of the evaluation process including identifying the goals of the evaluation, choosing the best data collection method, carrying out the study, analyzing the data, and sharing the results. This session will also share a number of resources to help support you in developing a basic evaluation plan of your own.

Talk link: `https://youtu.be/fKPimWQjvIQ`

What goes into planning and carrying out an evaluation?: At the most basic level, planning and carrying out an evaluation includes identifying the purpose of the evaluation, selecting data collection methods, identifying the sample, analyzing the data, and reporting results.

Evaluation Purpose: First, we need to identify the purpose of the evaluation. Two typical purposes of evaluation are for improvement (formative evaluation) and to measure impact (summative evaluation).

Formative evaluation takes place while a project is being developed. The purpose of formative evaluation is to identify areas of improvement to help ensure a project is meeting its intended goals and outcomes. Ideally, formative evaluations are an iterative process where data is gathered, changes are made, and additional data is gathered to see what additional improvements are necessary. Formative evaluation can look at areas such as comprehension, confusion, enjoyment, and ease of use.

Summative evaluation takes place when a project is out of the development phase. The purpose of summative evaluation is to measure the project's impact on intended audiences, or how well the project was able to meet its outcomes. Ideally, results from a summative evaluation can also be used to further improve a project, or inform future projects.

Data Collection Methods: We then need to identify how we are going to gather data to answer our evaluation questions. What methods are going to give us the type of information we need given the structure of the program we are evaluating and the audiences we are gathering data from? Data collection methods can include surveys, interviews, focus groups, interviews, and more interactive data collection methods.

Sample: We also need to think about the sample. Whom are we gathering data from and how will we obtain our sample? You might decide to collect data from everyone participating in a program, or you may want to select or recruit a sample of people.

Data Analysis: Our data collection methods can give us quantitative or qualitative data. We get quantitative data from things like closed-ended survey questions or tallies of observing particular behaviors using a checklist. We get qualitative data from methods like interviews or notes from freeform written observations describing what we are seeing. Often we want to use mixed methods in an evaluation, both quantitative and qualitative, as it gives us a more holistic view of the program.

Quantitative data are numbers, so we might look at simple counts or percentages. If appropriate, we might carry out statistical analyses. We often use graphs to visualize these results in reports and make the findings easier for readers to understand.

Qualitative data are descriptive in nature and can give us deeper insights into the experiences people are having. These data are often analyzed by creating codes that are applied to the data. These codes can be ones that you already have or codes that emerge from responses. After you code the data, you create themes based on those codes and report how frequently those themes appeared in the data. You might also include example quotes from the data in a report to help exemplify the findings.

Reporting: There are various ways you can share your findings. It might be a formal report or a brief or memo where you summarize findings in a more digestible format. Maybe instead of a report you have a meeting with program staff to discuss the results and make sense of the data together. There are a variety of ways you can share the data and it is important to consider the audience when thinking about the best way to share findings with them.

Resources:

The Center for the Advancement of Informal Science Education (CAISE) has a wide variety of resources to help you plan your evaluation on their website `informalscience.org`. Visit their

"Design Evaluation" section, as well as search their collection of thousands of evaluation reports to find examples you can learn from. Below is a list of additional resources that are helpful for designing evaluations of informal science education experiences.

- Center for Advancement of Informal Science Education. (2011). Principal investigator's guide: Managing evaluation in informal STEM education projects. Washington, DC: Author. urlhttps://www.informalscience.org/evaluation/pi-guide

- Feder, M. A., Shouse, A. W., Lewenstein, B., & Bell, P. (Eds.). (2009). Learning Science in Informal Environments: People, Places, and Pursuits. Washington DC: National Academies Press. Free download here http://www.nap.edu/catalog/12190/learning-science-in-informal-environments-people-places-and-pursuits

- Friedman, A. (Ed.). (2008). Framework for evaluating impacts of informal science education projects.

- Report from a National Science Foundation Workshop. From: www.informalscience.org/documents/Eval_Framework.pdf

- Fu, A.C., Kannan, A., & Shavelson, R.J. (Eds.) (2019). Evaluation in informal science, technology, engineering, and mathematics education. New Directions for Evaluation, 161. https://onlinelibrary.wiley.com/toc/1534875x/2019/2019/161

- Pattison, S., Cohn, S., & Kollmann, L. (2014). Team-based inquiry: A practical guide for using evaluation to improve informal education experiences. https://www.nisenet.org/catalog/team-based-inquiry-guide

Europlanet Evaluation Toolkit

Speaker: Anita Heward, Europlanet 2024 Research Infrastructure, University of Kent, UK

In this presentation, we will give a practical guide to the Europlanet Evaluation Toolkit (http://www.europlanet-eu.org/europlanet-evaluation-toolkit/), a resource that aims to empower outreach providers and educators in measuring and appraising the impact of their activities. The toolkit is intended to provide advice and resources that can be simply and easily integrated into normal outreach and education activities. The toolkit has been developed over a number of years with input from professional outreach evaluators and from active outreach providers within the planetary science community. The toolkit includes a brief introduction to evaluation, a choice of 14 data collection tools, worked examples of data analysis techniques, case studies and tutorials.

Talk link: https://youtu.be/d2bdL_oKMUA

Evaluation can provide essential information in understanding the effectiveness and accessibility of outreach activities in engaging diverse communities. In this presentation, we will give an overview of the Europlanet Evaluation Toolkit, a resource that aims to empower outreach providers and educators in measuring and appraising the impact of their activities. The toolkit is intended to provide advice and resources that can be simply and easily integrated into normal outreach and education activities. It is available as an interactive online resource at https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/, as a downloadable PDF and as a hard copy (including a book and set of activity cards).

The toolkit has been developed over a number of years with content provided by professional outreach evaluators Karen Bultitude and Jennifer DeWitt (UCL, UK). Initially, a series of focus groups and scoping discussions were held with active outreach providers from the planetary science community, in order to determine what they wanted from such a toolkit, and what sort of tools would be of most interest. A shortlist of tools was developed based on these discussions, with volunteers testing out the tool instructions once they were drafted.

The toolkit begins with a brief introduction to evaluation and steps to choosing the right tools. This advice takes the form of a series of questions to help design an evaluation approach and make the most efficient and effective use possible of limited time and resources. The toolkit offers a choice of 14 data collection tools that can be selected according to the audience (e.g. primary, secondary, interested adult, general public), the type of environment and activity (e.g. drop-in, interactive workshop, ongoing series, lecture/presentation or online) or according to when they might best be used (during, beginning/end, or after an event). The online version of the toolkit includes a set of interactive tables to help with the selection of which tool is most appropriate for any given situation.

The data collection tools are:

- Physical Ranking Scales: https://www.europlanet-society.org/evaluation-tool-physical-ranking-scales/
- Graffiti Wall: https://www.europlanet-society.org/evaluation-tool-graffiti-wall/
- Mentimeter: https://www.europlanet-society.org/evaluation-tool-mentimeter/
- Palm on Chest: https://www.europlanet-society.org/evaluation-tool-open-palm-on-chest/
- Geographic Location Map: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-geographic-location-maps/
- Snapshot Interviews: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-snapshot-interviews/
- Pre/Post Quizzes: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-pre-post-quizzes/
- Pebbles in a Jar or Box: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-pebbles-in-a-jar/
- Three Words: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-three-words/
- Target Evaluation: https://www.europlanet-society.org/evaluation-tool-target-evaluation/
- Post Event Surveys: https://www.europlanet-society.org/evaluation-tool-post-event-surveys/
- Photograph Diary: https://www.europlanet-society.org/evaluation-tool-photograph-diary/
- Peer Interviews: https://www.europlanet-society.org/outreach/europlanet-evaluation-toolkit/evaluation-tool-peer-interviews/
- Tweet Sentiment Visualisation: https://www.europlanet-society.org/evaluation-tool-tweet-sentiment-visualisation/

The toolkit also includes descriptions and examples of how to use two techniques (word-clouds and thematic coding) to analyse the data, as well as some top tips for evaluation and recommended resources. For some of the tools, the case study examples include information about how the tools have been used in the context of an event, how the data was collected and analysed, and what conclusions were reached, based on the data gathered. Over the past year, videos and training resources for using the toolkit have been added, as well as virtual alternatives to the physical tools. Case studies contributed by the community are very much welcome.

The Europlanet Evaluation Toolkit has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149 (Europlanet 2024 RI) and 654208 (Europlanet 2020 RI).

Assessing Students in the 21st Century

Speaker: Priscila Doran, NUCLIO / Project Coordinator, Portugal

Innovation in education has been a very much debated theme around the world and teachers have been making huge efforts to update their teaching methods. From shifting the classroom into a more student-centered environment to the use of games for learning and the personalized and individualized approach to teaching, education is suffering a huge transformation. However, one question is often asked by teachers, which is: "How can I assess my students when I teach in innovative ways?". When teachers shift their teaching methods and offer students a diverse and more personalized learning experience, the traditional standardized tests and exams become obsolete. If students encounter different learning opportunities inside the classroom and have the freedom to explore their own interests while learning fundamental life skills, it is natural to think that each student will acquire slightly different pieces of knowledge and retain different concepts at the same time. Therefore, a standardized assessment that focuses on such knowledge retention will not effectively portrait the real learning development of each student. Moreover, in an era where knowledge is easily accessed through a browser and a smartphone, it becomes imperative to shift the focus of student assessment. More than evaluating the ability to retain knowledge, it becomes important to focus both teaching and assessment in the development of fundamental skills like learning how to learn, critically thinking, innovation, divergent thinking, collaboration, communication, creativity, self-confidence, self-awareness, self-regulated learning, amongst others. Considering all the aforementioned it is important to develop innovative ways of assessing students so that assessment itself becomes a powerful tool in the learning process. Tools like checklists, rubrics and automated global assessment tools are proposed.

Talk link: https://youtu.be/aGE-8Ob3zmk

The system that we call today "traditional education" was once created to teach very specific skills and knowledge that would be required in very well-known lines of work where individuals would probably work throughout their lives [1]. However, the world has evolved and the very fast and accelerating technological development has changed the future perspectives of every student entering school, increasing the possibilities and unpredictability of their future.

Students entering school now will discover possibilities in their future that we might not imagine or predict today [2]. As a consequence, it becomes a futile attempt to try to determine what specific knowledge they need to acquire for their future career. Moreover, since knowledge today is readily available through one-click on a smartphone, rather than requiring students to memorize a whole list of concepts, it becomes much more important to focus on important core concepts and to teach students relevant skills for their future. Students in this century must learn how to learn, how to distinguish valid from non-valid information, how to think critically, how to be innovative and creative, how to communicate, how to be tolerant and respectful, etc. [3]

In order to achieve this, teachers have been making efforts worldwide to innovate in their teaching practice, joining innovative projects, using new tools, new methodologies and changing the classroom environment [4]. More importantly, education is becoming more inclusive and more personalized and this often raises an important question: "If we are offering a personalized learning experience, how can we assess our students"?.

When teachers shift their method into a student-centered approach and allow each student to explore learning at their own pace and according to their own interests and talents, it is natural that each student will learn differently and sometimes grasp different concepts. Furthermore, students will develop different skills and at a different pace. As such, using standardized assessment methods like tests and exams, that focus on memorized knowledge, becomes ineffective. Consequently, in order to properly innovate in their teaching, teachers also need to innovate in the way they assess their students.

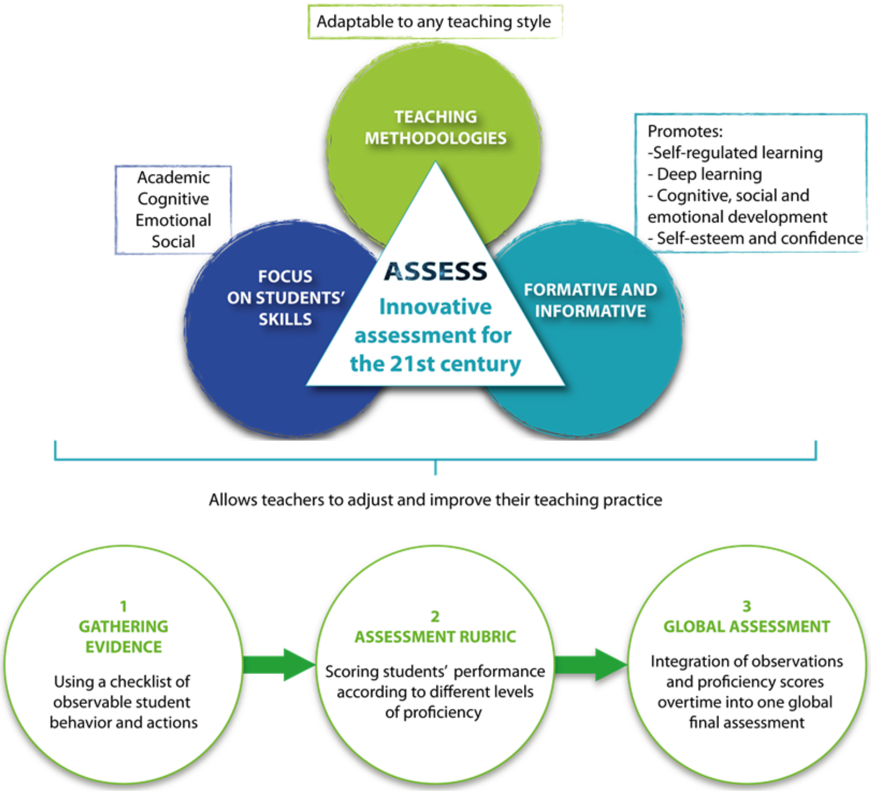
When used correctly, assessment can be a powerful tool for learning and for self-development, but in order to innovate and create a meaningful assessment for the 21st century, we first need to reflect on a few questions. The first question we should think about is: "why do we assess our students?" Do we assess them to give a final score, make them compete with each other and place them in a ranking that rewards them for their ability to memorize knowledge? Or should we assess students to provide them with the best support and self-awareness for the development of fundamental skills and invest in collaboration and acceptance instead of competition?

The second question is: "Are we being inclusive when we use a standardized assessment, like tests and exams?"

"Sometimes, the most brilliant minds do not shine in standardized tests, because they do not have standardized minds" - Diane Ravicht

Human beings are all different from each other and there is no such thing as a standard person. If we acknowledge this, then it becomes clear that assessment should not be standardized, but diverse, fluid and adaptable to each individual.

Student Assessment in the 21st Century



So, in order to solve the problem, we need to revolutionize assessment. And to do so, it is important to look at students' assessment from different perspectives. It is important to innovate not only the methods and tools that we use, but also the overall assessment, teaching and learning mindset.

We need to invest in an assessment methodology that is adaptable to any teaching style, that focuses on students' skills and that it is formative and informative, instead of judgmental. An assessment that is continuous throughout the learning process and that provides students with multiple opportunities for development and improvement. And through this, it also provides teachers the opportunity to continuously evaluate the effectiveness of their methods, as well as improve their teaching and adjust it to the needs of each class.

We need new tools that allow for an effortless and quick formative evaluation. In this presentation we propose tools like checklists, rubrics and an automatic global assessment that allow teachers and students to collect valuable information and have a visual representation of the development along the year. The checklists allow both students and teachers to regularly assess what has been achieved and what needs to be further developed. The rubric allows for a regular quantitative and qualitative evaluation of the proficiency and development of students in the different fields of assessment. And finally, the global assessment tool gathers all the information in one place and automatically creates graphics of each student's development in each field of assessment.

Finally, we need a completely new mindset on assessment and in the school as whole, where assessment is considered a powerful tool for the development of fundamental life skills. A mindset that promotes collaboration, tolerance and acceptance and where each student is treated and accepted as a unique human being and is valued by their qualities and talents.

NUCLIO is coordinating a project (The ASSESS project: https://assess.nuclio.org) that focuses entirely on the creation of an innovative mindset around student assessment and that will integrate innovative assessment tools into a digital app for teachers and students. We welcome all teachers, educators and all those who are interested to participate in the project, to share your ideas with us and to give us your contribution.

To have access and explore some new assessment tools, teachers can explore the assessment toolkits that were designed in the framework of two Erasmus+ projects: the IDiverSE assessment toolkit (https://idiverse.eu/idiverse-assessment-toolkit) and the POLAR STAR assessment toolkit (http://polar-star.ea.gr/content/assessment-toolkit).

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How did that happen? Mixed-method Evaluation of Astronomy Resources

Speaker: Sophie Bartlett, Cardiff University / Faulkes Telescope Project, UK

Astronomy is a well-known effective point of engagement, sparking students' curiosity and desire to learn. However, astronomy has a lot to offer; pretty pictures, a mind-blowing vastness, big telescopes, and application of much of the more mundane classroom science. As a result, it can be difficult to disentangle what specifically causes students' engagement. That is, what does an astronomy resource need in order to be effective and what other components are surplus to requirement? This presentation focuses on a PhD study involving 226 secondary school students that set out to answer this question. Focusing on both methodology and results, this presentation will explore how mixed-method evaluation can offer valuable information for developing and delivering effective astronomy resources. By using quantitative methods to identify what happens, and qualitative methods to identify why this happens and under what circumstances. Although mixed methods evaluation demands greater time and manpower, it can provide hugely valuable results that are not exclusive to a single resource, but that provide transferable findings that can be of use to future development and wider educationalists.

Talk link: https://youtu.be/VK_XnMB6wec

Astronomy is a well-known effective point of engagement, sparking students' curiosity and desire to learn (Salimpour et al., 2021; Osborne and Collins, 2001). However, astronomy has a lot to offer; pretty pictures, a mind-blowing vastness, big telescopes, and application of much of the more mundane classroom science. As a result, it can be difficult to disentangle what specifically causes students' engagement and positive learning experience when engaging with such materials. That is, what does an astronomy resource need in order to be effective and what other components are surplus to requirement?

A mixed method approach to evaluating such resources offers a valuable opportunity to capture this information. Its opportunities and strengths are argued here in the context of a PhD study involving ten case studies of secondary school classrooms that set out to identify how teacher-implemented astronomy resources can promote student learning experiences.

In a broad sense, evaluation is typically quantitative or qualitative. Quantitative approaches are used to explain a particular phenomenon through numerical data collection. They are deductive, objective and outcome-oriented. Qualitative approaches are inductive, subjective and process-oriented (Streefkerk, 2021). Each approach has its own advantages and disadvantages (see Streefkerk, 2021 for further detail). However, by combining the two methods we are able to surmount many of the individual limitations and utilise the individual advantages. As a result, the evaluator can gain a more holistic understanding of the phenomena at study. Where the quantitative data can provide an understanding of *what* happened, the qualitative data can give a more comprehensive understanding of *why* it happened (Johnson and Onwuegbuzie, 2004; Ivankova et al., 2006; Denscombe, 2008; Greene, 2008). This is particularly useful in formative evaluation, where you are looking to develop or improve resources or where you yielded negative responses. Evidence of poor or even negative impact in quantitative data is disheartening, but not understanding why such a result was yielded due to a methodological limitation can also leave you with little understanding of what caused such a result and what steps can be taken to improve results in the future. Although mixed methods evaluation demands greater time and manpower, it can provide hugely valuable results that are not exclusive to a single resource, but that provide transferable findings that can be of use to future development and wider educationalists.

Creswell and Plano-Clark (2011) also discuss the sequencing of mixed methods. They explain that depending on what method you implement first, your evaluation can be either explanatory or exploratory. Exploratory methods begin with qualitative methods and then generalisations are sought through a follow-up quantitative method. This is helpful if you are looking to make generalisations, perhaps if your resource was effective among a small student cohort, you would want to identify if it is effective among larger or additional cohorts.

Alternatively, explanatory methods first apply a quantitative phase in order to understand the general picture, and is followed by a qualitative phase in order to explore the patterns from the quantitative data and why such findings were yielded. An explanatory approach is helpful when you want to understand the processes and mechanisms behind the quantitative results, perhaps to inform future astronomy resource development.

In the case of this PhD study, a sequential explanatory design was followed as the researcher wanted to understand specifically what happened but also what processes and experiences led to those outcomes so that findings could be transferred to future and wider educational resource development. The quantitative method involved a closed-questionnaire consisting of Likert-scale items. The questionnaire was implemented on two occasions: before students had engaged with the astronomy resources, to reflect on these five areas in relation to their day-to-day science lessons, and after students had engaged with the resources, to reflect on their experiences when using the astronomy resources. The use of a parallel questionnaire pre- and post-engagement meant that direct comparisons could be drawn and also offered a tool that could be used with future resources.

For the qualitative arm, classroom observations, student focus groups and teacher interviews were implemented with a smaller subset of the audience. Classroom observations were carried out before astronomy resource implementation (during a ‘normal’ science lesson) and while students were using the astronomy resources. Focus groups and interviews were implemented after implementation of the activities. In line with the sequential explanatory design, the focus group and interview question schedules were informed and guided by preliminary results from the questionnaires and observations. This allowed the researcher to explore why such events took place and why students were or were not engaged.

This process of mixed method evaluation revealed five key elements that promoted positive learning experiences among students. Although these were identified in the context of particular astronomy resources, these elements are considered applicable to any activity or resource. Each of the five elements is now described, with accompanying relevant quote excerpts from students. 1. Processes of **investigation and exploration** that encourage students to follow the scientific process of gaining new knowledge: *"It was interactive, using real data. This makes it feel more relevant"*. 2. **Experiences of autonomy** gives students a sense of ownership over their learning: *"I liked the freedom of finding things out on our own"*. 3. **Novel, unexpected experiences** offer a 'wow' factor and provide an element of surprise: *"What? So that is the age of the Universe? I feel like Einstein!"*. 4. Providing students with opportunities to **cooperate and collaborate** with their peers helps provide a sense of relatedness (Gagne and Deci, 2005) *"It is easier to work off each other, like some people might have stronger points in that subject so they can teach other people stuff"*. 5. Embedding **effective differentiation** into resources to foster students' confidence and provide them with a challenging but achievable task: *"So I can do science"*.

However, despite the opportunities for autonomy and a student-centred classroom, the role of the teacher was still crucial in influencing students' experiences. Observations of each classroom revealed that despite using the same resource, implementation differed in each setting. Where teachers had a great awareness of individual learning needs among students, they were able to adapt the resources and embed appropriate differentiation. Additionally, great preparation from the teacher and familiarity with the resource led to more positive learning experiences among the students.

The results of this study provided valuable insight for educators and resource developers. The five key elements that were seen to promote positive learning experiences can stand as a foundation when developing a resource. Resource developers should recognise that resources will be implemented slightly differently in every classroom and thus should consider the teacher's role and their support needs. Resources should be adaptable and apply various scaffolds that can be added or removed in order to differentiate appropriately.

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Discussion summary

The presence in both sessions of all the speakers created the basis of very fruitful discussions about different aspects of evaluation. They stressed the importance of planning evaluation from the very beginning in the project design (even for short projects), in order to make the experience as positive, and its results more useful, as possible.

We discussed observation protocols in the evaluation process, in particular for young children, besides interviews and drawing pictures, pointing out the importance of evaluating the students' engagement level.

Similarly, it is important to note that when designing surveys with many types of questions, it is sometimes difficult to balance between a reasonable survey length and reliable results. Indeed, if the survey is too long, and it presents many open-ended questions, it could discourage people from compiling it. A suggestion is to verify that the duration of the compilation does not take more than about ten minutes.

Finally, we discussed the difference between evaluation and research: even if they are similar in data collection and analysis, they are different in their overall purpose. Research is about understanding phenomena and generalizing, while evaluation is about drawing judgement conclusions about quality, merit or worth. For both, anyway, it is important to respect some ethics requirements in data gathering and using. Some ethical guidelines have been developed by the American Evaluation Association (see https://www.eval.org/About/Guiding-Principles).

International Collaborations with an Educational Component

Session organiser: Alessandra Zanazzi,
INAF - National Institute for Astrophysics,
OAE Center Italy, Italy

Session overview

The session focused mainly on two aspects of international collaborations and networking activities that could be crucial for educators. On one hand, examples of international projects especially intended for education and communication to the public. These normally promote teacher training, networking occasions and activities and resources to share. They could also provide ideas, sometimes funding, always motivation, and inspiration to teachers and kids everywhere.

On the other hand, examples of international scientific big research projects that have a very interesting public part and educational component, which is of course very useful because it provides insights, data, ideas at the forefront of scientific research that are inspirational both for teachers and students.

Huge networks of teachers and activities with different approaches were presented, some of them "really international", others more local; examples of how international projects could be adapted locally; examples of networks for producing and sharing resources and activities on non-traditional innovative science (gravitational waves, cosmic rays), resources, training, and tools to engage the students and the public at best.

Astronomy Education in a World Without Frontiers

Speaker: Rosa Doran, NUCLIO, Spain

Astronomy is a very powerful tool to foster international collaboration. Education beyond borders will be the team of this presentation where the experience of 20 years of collaboration with people worldwide will be shared. The recent pandemic has strengthened and opened an opportunity for global collaboration but has also brought to light the dangers of gender imbalances, stereotypes and the challenges of the digital divide. Strategies to tackle this and other aspects for a truly global collaboration will be presented.

Talk link: https://youtu.be/E3dw1tgiP-w

The main objective of this talk is to share with the audience our experience in teacher training and its importance not only for the spread of Astronomy per se but also to create awareness of the importance of its understanding for a more human friendly attitude to life on Earth.

One of the missions we have as astronomy educators is to empower educators to promote astronomy learning in a more innovative way and ensure that students and their families understand and recognize the importance of Astronomy in our daily lives. There are many international programs devoted to the professional development of educators in the field of Astronomy. I am presenting the ones that are known to me, probably forgetting many other important ones. Listed below are the links to the ones mentioned in my presentation, in alphabetical order:
CESAR - https://cesar.esa.int/
COSPAR panel of Education - https://cosparhq.cnes.fr/
ESERO - https://www.esa.int/Education/Teachers_Corner/European_Space_Education_Resource_Office
European Association for Astronomy Education - https://eaae-astronomy.org/
European Hands-on Universe - http://www.euhou.net/
European School Innovation Academy - https://esia.ea.gr/
Faulkes Telescope - https://www.faulkes.com/faulkes-telescope-project
Galileo Teacher Training Program - http://galileoteachers.org/
Global Hands-on Universe - http://handsonuniverse.org/
IASC - http://iasc.cosmosearch.org/
International Planetarium Society - https://www.ips-planetarium.org/
IUCAA - https://www.iucaa.in/

Las Cumbres Observatory - https://lco.global/education/
NASA - https://www.nasa.gov/hrp/education
NASE - http://sac.csic.es/astrosecundaria/en/Presentacion.php
OAD - https://www.astro4dev.org/
Office of Astronomy for Education - https://www.haus-der-astronomie.de/OAE
Space Awareness - http://www.space-awareness.org/en/
Universe Awareness - https://www.unawe.org/

Although these are quite a few programs, they are in fact far from enough, led by amazing people willing to make this world a better place through education. I will focus on a couple of them, the ones that I am more involved with. The main driver of our efforts is the Galileo Teacher Training Program (GTTP), inspired by the methodology created by the Global Hands-on Universe team. GTTP is a movement of educators at a global level. It does not produce resources but rather supports and endorses the organization of teacher training events. Each event is organized locally and in order to be officially recognized, the training event has to incorporate the following elements:

- Information Communication Technology (ICT) tools such as planetarium software, image processing software, simulators, etc.
- One or more topics of astronomy following a specific list of suggested topics.
- Inquiry and Project-Based Learning and interdisciplinarity.
- Observations of the Sun and/or night sky (naked-eye or with telescopes).
- Integrating at least one of the UN Sustainable Development Goals.
- The adoption of an inclusive approach (UDL for instance)

The Global Hands-on Universe (GHOU) educational efforts and GTTP managed to reach over 70 000 educators worldwide in various types of activities: teacher-training events, big activities, small activities, participation in projects, etc. Every country highlighted in the map has at least one national representative that has helped organize one or more activities in the region. One example of such activities is the Cosmic Light EDU teacher training, an effort that emerged during the International Year of Light in 2015 and counted on the support of the IAU. Another example is the Open Astronomy Schools initiative that incorporated the activities during the celebration of the IAU100 anniversary. GTTP partners with several organizations and events to enrich the offer to educators and also extend the coverage to regions that can benefit from these events where scientists, trainers and educators are sharing their best practices, exchanging ideas and creating a strong community of astronomy education innovators. Some examples of this collaborations are:
Astronomy Education Adventure in the Canary Islands: http://galileoteachers.org/astronomy-education-adventure-in-the-canary-islands-2021-online-course/
COSPAR K: https://www.cospar2020.org/stem/
Journey to Space Exploration:
https://cesar.esa.int/index.php?Section=Events&Id=198
Global Hands-on Universe: https://handsonuniverse.org/ghou2021/

In the end, the main aim is to ensure educators are equipped with the necessary tools to enthuse students towards a better understanding and appreciation of astronomy and science as an overall. During the training events, high importance is devoted to 21st century skills, to the sustainable development goals, to the use of ICT to enhance learning, to the use of Open Educational Resources and the adoption of inclusive attitudes. But the training is not all that is necessary, the training events are just part of a much broader strategy that uses what we call the 5 Pillars of Community Building". There are 5 phases that need to be in place in order to achieve a proper adoption and implementation of the opportunities presented to educators: Engagement, Training, Support, Recognition and Community. During the training events some elements are very empowering. The integration of real data to enable the feel of an authentic discovery, the work with scientists, the replication of scientific discoveries and the possibility to dive into real research experiences, such as the discovery of supernovas, asteroids, the observation of exoplanets, etc. The importance of careers in space exploration and astronomy research is also highlighted during the events, trying to avoid stereotypes in terms of gender, abilities and competencies.

The major goal in the end is to help educators raise generations of science-literate individuals, capable of making wise decisions, grounded on critical thinking and on the solidity of science.

Finally, in order to help everyone recognize that we live in the same world, that we are all humans under the same sky.

Benefits Global Science Outreach Programs Bring to Educational Initiatives

Speaker: Jorge Rivero González, Joint Institute for VLBI ERIC (JIVE), The Netherlands

Astronomy is considered a gateway science for education due to its ability to encompass many subjects present in school curricula worldwide, inspire curiosity and foster critical thinking. In this sense, astronomy education initiatives are a keystone for global public engagement programs organised in recent years such as the UN IYA2009, IYL2015 or the IAU100 initiative. Among their benefits, these programs mobilise economic resources, distribute and support localisation of educational resources and foster organisation of initiatives to reach communities that have little or no access to these types of actions, e.g. GalileoMobile project. In this talk, I will present lessons learnt from designing, coordinating and implementing international collaborations with educational components.

Talk link: https://youtu.be/voaeQ6qgtgg

In this summary, lessons learnt from designing, coordinating and implementing international collaborations with educational components are presented.

Why astronomy for education?

Astronomy is the perfect tool for development, education, diplomacy and outreach and, indeed, there are a wide variety of examples of projects that help support the UN Sustainable Development Goals (https://sdgs.un.org/es/goals). If we look specifically into education, astronomy is considered a gateway science for education [1] due to its ability to encompass many subjects present in school curricula worldwide, inspire curiosity and foster critical thinking. Astronomy has been indeed identified as the favourite topic for boys and girls in many countries around the world [2].

International initiatives with educational components

Astronomy education initiatives are a keystone for global public-engagement programs organised in recent years such as the UN IYA2009 (https://www.astronomy2009.org/resources/documents/IYA2009_Final_Report/index.html), IYL 2015 (https://www.light2015.org/Home/About/IYL-Final-Report.html) or the IAU100 initiative (https://www.iau.org/static/archives/announcements/pdf/iau100-final-report-ann20019.pdf). These initiatives have reached hundreds of millions of people around the world and comprised the key aspect of astronomy/science for education as one of their goals. Other interesting initiatives are the EC-funded Universe Awareness (https://www.unawe.org/), Space Awareness (http://www.space-awareness.org) and spaceEU (https://www.space-eu.org/) projects, which reached 1 million students with their actions. Another example is a project that specifically works with underrepresented communities, such as GalileoMobile (www.galileomobile.org), which since its foundation in 2009 have shared different cosmovisions under the same sky and reached over 17,000 students and 2,000 teachers in 15 countries.

Benefits of global science outreach programs for educational initiatives

Community Engagement: global astronomy outreach programs mobilise the international communities of amateur astronomers, communicators and educators. Examples of these are the 100 Hours of Astronomy in 2009 and 2019 or the Astronomy Day in Schools in 2019 that included many activities with educational components inside or outside schools. These types of initiatives also provide opportunities for the development of innovative approaches and for people to start their involvement in astronomy education.

Production, localisation and distribution of resources: global astronomy outreach programs attract institutional support, bringing funding for the production of educational resources, which are fundamental for communities that could not afford basic materials. Prominent examples of resources produced through international projects are the Galieoscope (Pompea et al., 2011), the Universe in a Box (https://www.unawe.org/resources/universebox/), and the IAU astroEDu platform (https://astroedu.iau.org). However, it is important to notice that the production and distribution of resources are not enough. Localisation is equally important with translations and the adaptation of materials/activities to local reality to make resources relevant to local teachers.

Understanding National curricula: international collaboration contributes to learning about different realities of educational systems and international projects bring the expertise and opportunities for it. As an example, the Space Awareness Project made a preliminary study in 2016 about how astronomy was present in school curricula in the 11 countries where its activities were implemented as a basis for the production of their own activities. Another recent example is the review of astronomy on educational systems in 66 done by the IAU OAE National Astronomy Education Coordinator Teams (https://www.haus-der-astronomie.de/oae/worldwide).

Teacher Training: international initiatives bring opportunities for funding for the organisation of teacher training, see initiatives from the Galileo Teacher Training (http://galileoteachers.org/) or the NASE (http://sion.frm.utn.edu.ar/nase-prueba/) programs during IYA2009 and IAU100. In recent years, The co-creation of programs and work with pre-service teachers have also been important in order to introduce the benefits of astronomy in workshops that involve teachers at the first stages of their careers.

Promote inclusive actions: a key aspect of global outreach initiatives is emphasising the participation of underrepresented groups. Examples such as "A Touch of the Universe" (https://www.uv.es/astrokit/) project or the IAU "Inspiring Stars" (https://sites.google.com/oao.iau.org/inspiringstars) exhibition inspire our community and encourage people to not leave anyone behind as we reach for the stars.

Sustainability: It is very important when organising global programs to consider early on the sustainability of your actions. For educational activities, it is very important to train teachers so that they eventually continue using astronomy in their classrooms. As far as sustainability is concerned, especially working with underrepresented communities, lessons learnt from the GalileoMobile project show the importance of continuous contact with communities. For instance, the Amanar project (https://www.galileomobile.org/amanar) that supports the long-standing refugees of Western Sahara, started the e-Amanar project, which used the WhatsApp platform to implement continuous capacity-building support to Sahrawi teachers.

Education is the most important tool that can be used to change the world. It is our job as an international community to learn from each other and work together toward this goal.

References:

1. The Gateway Science: a Review of Astronomy in the OECD School Curricula, Including China and South Africa - Salimpour et al. (2020)

2. The ROSE project An overview and key findings - Sjøberg and Schreiner (2010)

The AWB Nigeria Experience

Speaker: Olayinka Fagbemiro, Astronomers Without Borders (AWB) Nigeria, Nigeria

AWB Nigeria has over the years collaborated with various international organizations in the effort to take Astronomy to every child in the country. Without the support of these partners, it would have been very difficult to reach the thousands of kids reached to date. Supports have been in the form of resources, funding and human resources. Nigeria being a country where Astronomy is not taught in schools at both Elementary and High School levels, the teachers have had to rely on other means of incorporating Astronomy into the curriculum mostly through extracurricular activities. AWB Nigeria has enjoyed the support of partners in carrying out Astronomy outreach, competitions, among others. Also, being part of various workshops, conferences, symposia, etc. has exposed members to international best practices in Astronomy Education.

Talk link: https://youtu.be/k27zAVRT8MY

The Astronomers Without Borders (AWB) Nigeria, is a non-governmental organization with the aim of spreading Astronomy and its benefits throughout Nigeria. AWB Nigeria organizes astronomy-based events on a regular basis. Astronomical events, which capture the popular imagination, create excitement and generate media attention.

Our organization uses astronomy as a tool to inspire children and as a starting point for continuing STEM education in their schools. Our scope also involves the development of school extracurricular activities that will drive STEM Education in schools, teacher training, setting up of Astronomy clubs in schools and other science-based outreach activities.

The need for collaboration in Astronomy Education in Nigeria arises since Nigeria is a country where Astronomy is not taught in schools either at elementary or high-school levels. Teachers have had to rely on other means of incorporating Astronomy into the curriculum, mostly through extracurricular activities. Nigeria has a really low number of Professional Astronomers. Lastly, without collaborations, the scope of engagement in Astronomy would have been too small and based on the prevailing circumstances. The benefits of collaborations in Astronomy for developing countries are the expansion of Astronomy Education scope, exchange of knowledge about international best practices in the teaching of Astronomy, teacher training, hands-on resources and exchange programs for school kids.

The past and current, local and international collaborations by AWB Nigeria are the Nigerian Space Agency, Defence Space Administration, the National Commission for Refugees, Migrants and Internally Displaced Persons, Office of Astronomy for Development (OAD), Astronomers Without Borders (AWB) International, SSVI, Vixen Company, Japan, ASGARD, Belgium, and

UNAWE. Some of these can be found in the following links:
https://awbnigeria.org/covid-19-support-for-internally-displaced-persons-project/
https://awbnigeria.org/idp-children-astronomy-outreach-project/
https://awbnigeria.org/astroart-competition-organized-by-the-ohio-state-university-department-of-astronomyfirst-place-cornelia-egbodor-from-nigeria-age-13-e-t-extra-terrestrial/
https://awbnigeria.org/asgard-near-space-experiments/

The challenges of international collaboration in Astronomy Education are the differences in time zones, differences in school curricula, heavy custom duty on donations from abroad, and the high cost of shipping materials from abroad.

A Journey of a Thousand Miles Begins with a Single Step: Education in International Collaboration

Speaker: Beatriz Garcia, ITeDA (CNEA-CONICET-UNSAM) and National Tech. University-Mendoza, Argentina

In the era of multi-wavelength and multi-messenger Astronomy, the cooperation in multidisciplinary collaborations is part of the development of the discipline. This approach is also an opportunity to innovate in education, opening a new door to the knowledge using strategies designed from the beginning of the experiments and which are part of the Project Management. In this contribution we will present the formal framework and challenges that conform the road map for education of non-traditional topics and non-traditional detection, from the moment in which the idea of the contact with the community is born, until the moment in which the collaborations open the original data for public uses, especially in education, is part of the activities inside large collaborations. As an example and evidence of the meaning of education in a big collaboration, we focus on the Pierre Auger Observatory (https://www.auger.org/), located in Malargüe, Argentina, the largest observatory available for measuring ultra-high-energy cosmic rays. Along with important scientific discoveries, education and outreach work has been carried out across the 18 participating countries and online.

Talk link: https://youtu.be/-bvVZSHlSoo

Management in Education and Outreach: Beyond Management, the organization of the Collaboration consisted in task groups, led by task and co-task leaders. The activities are planned, discussed inside the Task Force, submitted to the Collaboration Board, and performed or implemented. One of the tasks is Outreach. Big projects bring together expertise from frontier scientific research and educational research in formal and informal science learning, along with user communities, to demonstrate how even Nobel Prize-winning science can be systematically integrated into the school curriculum.

Design thinking and continuous upgrade as a strategy: Design thinking is a non-linear, iterative and a User-Centred process that teams employ to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test. Involving five phases — **Empathize, Define, Ideate, Prototype, and Test** — it is most useful to tackle problems that are ill-defined or unknown. This is the framework for Education and Outreach design in Pierre Auger and many collaborations.

The Pierre Auger headquarters was designed with a VC, which was inaugurated in 2001 and it is a "living" space, which is upgraded permanently, in the same way, and with the same vision as the detectors. This Center welcomes on average 8000 visitors a year. Permanent and temporary exhibitions have been prepared both in reality and virtually. Most of the activities and resources are available in English and Spanish.

Successful histories of the PA: As part of the community of Malargüe, every year the Pierre Auger Observatory takes part in the parade celebrating the anniversary of the town, it has promoted the creation of a devoted Argentinian Stamp, the installation of the James Cronin High School, the development of science fairs for elementary and high-school students from all the country every 2 years. It has given the support for the installation of the first digital Planetarium in Argentina, presented the initiative for the Ordinance 1298/15 on Dark Sky Protection in Malargüe (sanctioned on Abril, 14 2005). It installed one of the first interactive VC of a scientific institution in the country with a virtual visitor tour available in English and Spanish; this can be found in the website of Auger (izi) and has become very important during the lockdown period, when the visits in person have been very limited. Several activities were organized in order to highlight the importance of the work in science developed by women.

Open Access Data and Masterclasses: In 2021 the Collaboration decided to release 10% of the data used for the results reported at the International Cosmic Ray Conference 2019. The purpose of the release is to allow a wide community including professional scientists, people interested in education and outreach initiatives, and citizen scientists to re-use the data in their projects. This first sample amounts to over 20000 showers measured with the surface detector array and over 3000 hybrid events obtained from the surface and fluorescence detectors.

The Master Classes have been a very powerful tool to get high school students involved in the work made in the big experiments for years. The Pierre Auger Collaboration has prepared Master Classes to reinforce outreach efforts.

Virtual Visits (VV): Between 2020 and 2021 PAO started the Virtual Visits to the Observatory completely synchronous, mainly as a consequence of the pandemic. The idea arose from the contact with Frontiers from H2020 and was extended to more visits not only in English, mainly for European countries, but also in Spanish for Latin America. This activity completely modifies the way to communicate science to the public, required training for the local guides for the online transmission of the visit, allows the assistants to know all about Pierre Auger, and see normally forbidden areas (like the Assembly Building, where the detectors are prepared or the Central Data Acquisition area).

Synchronous VV permits immediate feedback from the public. After the VV a survey is sent to all the participants to collect opinions, feelings, suggestions and ideas and assure a permanent improvement of the activity. These visits increased the number of visitors by more than 100% and will continue beyond the pandemic restrictions in a hybrid format.

A new experience: QUBIC Collaboration: Based on the experience in PAO, QUBIC Collaboration started the Education and Outreach activity in San Antonio de Los Cobres. QUBIC, an acronym that means Q-U Bolometric Interferometer for Cosmology, is a very innovative instrument to study the CBM. It is under assembling at this moment in Salta city and will be installed in Alto Chorrilos, near SAC at 5000 masl in 2022.

Not a lonely project: The Research Infrastructures FOR Citizens in Europe project (REINFORCE; https://www.reinforceeu.eu/), developed under the Project REINFORCE (GA 872859) with the support of the EC Research Innovation Action under the H2020 Programme SwafS-2019-1, aims at engaging and supporting citizens to cooperate with researchers and actively contribute to the development of new knowledge for the needs of science and society. Four demonstrators are ready to be launched as Citizen Science projects using the Zooniverse platform, assuring accessibility through the sonification of the data.

Inherent to International Projects, a special mention of cooperation in the development of Citizen Scientist proposal combining the know-how of different groups, institutions and Collaboration, is also deployed. Good communication media must be available using different tools like websites, networks, YouTube channels, access to open data, guided visits (face-to-face and virtual), satisfaction surveys, Citizen Scientist projects, open classes.

The participation in a collaboration means several responsibilities, because the communication of the results with the public must have the agreement of all the members and is an opportunity to learn from other institutions, groups and scientists with a great experience in outreach showing that "**A journey of a thousand miles begins with a single step**", according to the Chinese proverb, and the possibilities along the road are, as the wavelengths and the messengers, multiple, as well as the challenges.

References: Caballero Mora, K.S, for the Pierre Auger Collaboration, Outreach activities at the Pierre Auger Observatory, 37th International Cosmic Rays Conf. (ICRC), PoS(ICRC2021)1374 - Proceeding of science, 2021.

IGrav: Engaging People Throughout the World in Exploring the Exciting Field of Gravitation

Speaker: Magdalena Kersting, University of Oslo, Norway

The mission of IGrav (the International Gravity Outreach Group) is to engage people throughout the world in exploring the exciting field of gravitation, and in particular gravitational-wave and multi-messenger astrophysics. IGrav will accomplish this mission through the creation, sharing, and dissemination of a variety of educational and outreach resources. In this talk, we will discuss how we can create opportunities and promote knowledge transfer across international collaborations, and how we can find the most effective ways of working together within the astronomy & astronomy education community. One particular focus will lie on creating a platform to determine best practices and promote education and evaluation efforts in astronomy education.

Talk link: https://youtu.be/lGBu8z307xM

We discuss the creation, sharing and dissemination of education resources across international astronomy and astrophysics collaborations.

Why do we collaborate within IGrav?: We care about educating future generations and establishing public understanding of the scientific process. We want to find effective ways of working together within the gravity community. Through collaborative efforts in education & outreach, we hope to accomplish more than individual members of our gravity community could accomplish alone. We are pretty global. We have an Indico category hosted at EGO in Italy, mailing-lists hosted at LIGO Livingston, a website hosted in Caltech, and a wiki hosted in Glasgow.

We continue to gather enthusiasts and advocates for gravitational-wave education & outreach. By collaborating across universities, countries, and organisations, we can extend our reach through extended networks and shared resources and methods. Bringing together different perspectives to use complimentary approaches and pool educational efforts and expertise in gravity education & outreach. Pooling efforts provide insights into the efficacy of our approaches, which allows improving their quality and tailoring them to the needs of different groups of audiences.

What can we do and achieve? Development of IGrav:
2018: Virgo-LIGO-IPPOG meeting in Pisa
2019: 1st meeting in Valencia (Amaldi 13 & GR 22)
2020: 2nd (virtual) meeting (LISA symposium)
2021: IGrav becomes a subcommittee of GWIC (Gravitational Wave International Committee)

IGrav is organized into six working groups: Formal education & evaluation, Science festivals, Art and science, Multi-messenger astronomy, Diversity, equity and inclusion, Igrav governance, and Communications & governance. The IGrav Formal Education & Evaluation working group gathers passionate physicists, educators, and teachers with a shared interest in formal education and evaluation of education and outreach efforts in topics of modern gravitation and gravitational waves. The group aims to create a platform to share existing resources, determine best practices, and promote formal education and evaluation efforts.

How to promote education efforts?: We do not want to reinvent the wheel. We have started to compile lesson plans and **resources**, including relevant curriculum links. Eventually, we aim to set up a **repository** on the IGrav webpage. How can we incorporate our resources in teacher professional development **workshops** and programs? Our main challenge is to reach **teachers** and instructors.

IGrav (www.igrav.org) will continue to support and sustain our gravitation education & outreach community.

But Do They Understand Me? How to Make Astronomy Beliefs Visible and What to do When You Find out

Speaker: Linda Shore, Astronomical Society of the Pacific, USA

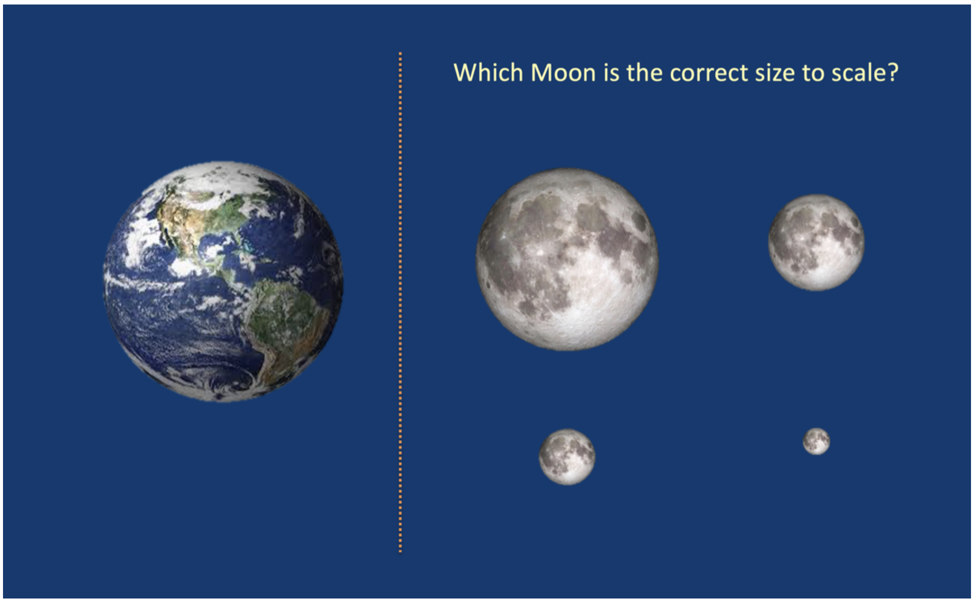
Collaborators[1]: Suzanne Gurton (National Radio Astronomy Observatory), Anna Hurst (Astronomical Society of the Pacific), Kari O'Connell (Oregon State University), Dennis Schatz (Institute for Learning Innovation)

Whether you are an astronomer communicating with the public, a museum educator leading planetarium experiences, or a teacher working with students, knowing what your learners are thinking "in the moment" is key to successful engagement. The Astronomical Society of the Pacific has been developing "feedback tactics" scientists and science educators across the globe can use to spark audience curiosity and make audience thinking visible. The ASP also provides scientists with training and support on how to interpret feedback they get and modify their presentations based on responses. In this session we will introduce you to engaging astronomy feedback tactics you can use in a science classroom, museum, or under the stars.

Talk link: https://youtu.be/cnj9uGFuKtk

How many of us, as educators, have led an astronomy lesson and wondered whether our students are learning? Are our explanations making sense? Are our demonstrations helping make the

[1]Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



Example of an astronomy poll used in a virtual public engagement event.

concept clear? Are we using too much jargon? Was the hands-on activity effective in addressing preconceptions? Regardless of whether the students are young children in elementary school, families visiting a planetarium, or adults attending an evening lecture, the fundamental question all educators ask themselves is the same: *are they understanding me and if they are not, what can I do right now to change that?* Knowing what learners think, feel, and believe "in the moment" and using that knowledge to make immediate adjustments to a lesson is the key to successful teaching (NAP, 2017). While most educators know this and strive to engage their students in authentic investigations and lively discussions, too many of us still forget to check in with our learners, observe and listen carefully to what they have to say, and respond to their feedback in ways that will spark curiosity, increase interest, and enhance learning.

The Astronomical Society of the Pacific, in partnership with Oregon State University, the Institute for Learning Innovation, and the National Radio Astronomy Observatory are working collaboratively to develop tools and resources for professional astronomers designed to help them use engaging "feedback tactics" to make audience thinking visible. The project also provides scientists with training and support on how to interpret the feedback they get and modify their presentations based on audience responses While the OTSF project focuses attention on helping professional astronomers, the tactics and approaches we are developing can be used by any astronomy educator, in a variety of venues, and with learners of all ages and backgrounds. The project is funded by the National Science Foundation, NSF DRL AISL #18110222, *The On-The-Spot Feedback Project.*

What is a "feedback tactic" and how do you design them? Tactics include polling an audience, having learners use models to show what they think, engaging learners in kinesthetic activities, and interpreting student drawings (see Table 1). There are many ways to get audience feedback and the tactic you choose often depends on the age and background of the audience, as well as the goals for the astronomy lesson. For example, when working with very young children, kinesthetic activities and drawings are often a better way for them to articulate their thinking. What all successful tactics have in common is that they not only make audience knowledge visible to the educator but can (and should) spark curiosity and interest. The Figure above is an example of an audience/student poll that we recently shared with astronomers leading virtual public engagement events. The COVID-19 pandemic forced almost all education venues to pivot from "face-to-face" to entirely virtual instruction. We found that audience responses could still be collected in engaging ways using the annotation function included in video conferencing platforms, like Zoom.

Using, interpreting, and responding to responses to audience feedback is part of a larger approach to audience engagement our OTSF Project promotes and includes Planning, Implementing, and Reviewing. *Planning* includes knowing the background and expectations of the learners and setting specific goals (Besley and Dudo, 2018); *Implementing* involves gathering audience responses and responding in the moment (NAP, 2017); *Reviewing* is done at the conclusion of the event and requires educators to reflect on what aspects of the lesson worked and what can be improved in the future. Table 2 summarizes the steps that define successful science engagement.

Resources:

- The On The Spot Feedback Project Website (under construction): https://astrosociety.org/education-outreach/higher-education-and-early-professionals/on-the-spotfeedback.html

- National Academies of Sciences, Engineering, and Medicine 2017. Communicating Science Effectively: A Research Agenda. Washington, DC: The National Academies Press. https://doi.org/10.17226/23674.

- Besley JC, Dudo A, Yuan S. Scientists' views about communication objectives. Public Understanding of Science. 2018;27(6):708-730. doi:10.1177/0963662517728478

Table 1: Examples of "Feedback Tactics" in Astronomy

Polls	*"Which shape most closely represents the way Mars orbits the Sun."*
Drawings	*"Draw what you think the Moon will look like in a week from now."*
Building & Using Models	*"Using two coins to represent the Milky Way Galaxy and the Andromeda Galaxy, show me how far apart you think they are in space, to scale?"*
Kinesthetic activities	*"With your partner as the Earth, can you be the Moon and show me how you move in space during a month?"*
Open-Ended Questions	*"Why do you think it's hotter in the summer months compared to the winter months?"*

Table 2: Designing Successful Science Engagement Activities and

CYCLE	ELEMENTS	DETAILS
PLAN *Before the Event*	Learn	• About your audience • About the event and venue • About audience expectations
	Decide	• Your main engagement goals • What to assess and monitor
	Develop	• Feedback tactics you'll use • Alternative approaches and activities
IMPLEMENT *During the Event*	*Check the Audience*	• Audience reactions and responses to tactics
	Observe the Audience	• Identify audience preconceptions, beliefs, understanding, etc.
	Respond to the Audience	• Make needed adjustments • Add, revise, or skip activities, if needed
REVIEW *After the Event*	Reflect	• What worked? • What can be improved?
	Revise	• Make changes to how you facilitate the event • Make changes to the activities • Make changes to the tactics used
	Repeat	• Design a revised event • Lead new event and follow the same steps

Discussion summary

The discussions at the end of the sessions focused on different aspects: first of all the language and adaptation issues emerged strongly. The speakers and the participants stressed the need for translating but also of adapting, contextualising and "decolonising" the activities proposed in the framework of international projects. This need for inclusion is, of course, particularly acute in the case of collaborations, which by their nature involve several countries, languages and cultures. One way could be thinking – or re-thinking – the activities so that, for example, there is less need for written content, they use more visual materials.

Another issue is the sustainability of the projects - not all local communities can think of financially supporting international education and training efforts on their own. It is the responsibility of the projects to help, for example, by empowering the local teachers that will provide a multiplier effect. This model of empowering others to do things is very frightening but enables us to reach out to more and more people. Also, whatever the project, it has to be flexible enough so that the local community can use local materials and resources and it can be empowered to adapt according to what they have. The actions of projects should help the local communities to sustain their own programs and should take an open, bottom-up approach so that they can be engaged in the implementation from the very beginning.

We also discussed the lesson learnt from the pandemic: the need to organise online low-cost events has allowed us to see 'new faces' of people that would not have been able to travel long distances and participate in person (for example, in teacher training activities, or at conferences). This has allowed the involvement of people from disadvantaged and remote areas and indeed from all over the world. This, while not replacing face-to-face interaction, offers huge advantages that must be taken into account.

Low-Tech Astronomy Education

Session organiser: Rosa M. Ros, Polytechnic
University of Catalonia, Spain

Session overview

The general opinion suggests that poor technology is equivalent to poor education. After the two sessions of Low-Tech Astronomy Education, the general approach from many participants was completely different from the previous conception. Low-Tech seems simple at the first approach but helps to introduce very difficult concepts. Low-Tech promotes motivation for students and teachers, practical demonstrations, and models and analogies in teaching. Low-Tech helps to get a deep understanding in the process of learning through the hands-on approach. It promotes that students feel as the protagonist of their learning process. Low-Tech promotes the highest comprehension of the students and is useful in all the countries: with different degrees of technological advancements. Low-Tech is used with young and experienced teachers.

In this session, the invited speaker Beatriz Garcia, from Argentina, gave several examples of Low-Tech methodology and explained the philosophy of this project. Tan Hoe Teck from Singapore presented a simple planetarium constructed by his students. In-Ok Song from South Korea explained the successful example of the NASE course in her country. Corina Toma from Romania presented an example using Low-Tech methods in the classroom after many years of experience in this area. Breezy Ocaña showed an example of a NASE course in USA and Dominican Republic and presented results from a survey in order to show low- and high-tech comprehension of the students, and finally, Deodatus Kiriba, from Tanzania, mentioned the results of an example of the NASE course in his country.

Additionally, there were 5 posters contributions. Jorge Rivero from The Netherlands, explained a special project with Sahrawi Refugee teachers, Rupesh Labade from India, described a mobile-application used to teach astronomy, Hassan Baghbani from Iran introduced a festival for students with Low-Tech materials, Akihiko Tomita from Japan presented an adapted model from a NASE demonstrator, and Mahdi Rokni from Iran presented a relationship between astronomy, literature, and poems from a Low-Tech point of view.

This session was curated with the help of Boonrucksar Soonthornthum (Thailand), Noorali Jiwaji (Tanzania) and Beatriz Garcia (Argentina).

Inexpensive/Cheap/Low-cost Astronomy and Quality: Between Prejudices and Reality

Speaker: Beatriz Garcia, ITeDA (CNEA-CONICET-UNSAM), National Tech. University-Mendoza, Argentina

Astronomy is the oldest scientific discipline to which Humans dedicated time in a systematic way. The knowledge grew exponentially in the last centuries and also the technological needs of the astronomers to decipher the Cosmos. But, is the knowledge and comprehension of the main concepts of the discipline also connected with the new technologies or you can teach and learn first level astronomy at a low-cost?. What really means "inexpensive" in a world where the technology is dominant, but has no sense for the most part of the people? The idea of this session is to show how understand big discoveries with low cost resources and discuss the impact, with some examples, of educating and developing the critical thinking in the new and overloaded with technology generations.

Talk link: https://youtu.be/dEU24GETAJk

Astronomy is the oldest scientific discipline to which Humans dedicated time in a systematic way. From the past to the present, the knowledge grew exponentially and also the technological needs of astronomers to pursue their objectives: to decipher the Cosmos.

New Methodologies are needed: Methodology in Education plays a fundamental role at the time to transmit concepts in Astronomy. The organization of knowledge starts with the first steps of humans to decipher the movement of the planets and the stars, until the Standard Model of the origin, evolution and possible future scenarios for the universe. In this sense, different approaches to the process of teaching/learning are important, mainly, if the idea is to assure that the students understand how nature works. The didactic of Astronomy can not be faced only in one way and must be thinking for all, in a frame of reference in which education is inclusive and sustainable.

Low-cost vs quality teaching: One question that a teacher can ask while preparing material for classes can be if quality teaching of the discipline is only possible using new technologies or if it is possible to teach high quality Astronomy at low-cost with inexpensive materials. Perhaps, we also need to define what really means "inexpensive", in a world where technology is dominant (and sometimes not very expensive), but where that technology has no sense for most people. The highlight of this contribution is to show that the understanding of big discoveries is possible

Figure 1: Material to prepare the activity for expansion of the universe and detection of radio wavelengths.

using low-cost resources and materials. The focus of the discussion should be on the teaching practices and the impact on educating new generations that are overloaded with technology.

Hand-on activities, learning by doing: We propose to make an approach, for different topics in Astronomy, through some examples to help understand what we say when we propose low-cost activities. These two examples are, a) the radio wave detection and b) the explanation of the Hubble-Lemaître Law. In both cases, we just need material that we have at home or are very easily available at a market (see Figure 1).

The approach presented in this contribution is based on the Network for Astronomy School Education-NASE Program (Ros, et al. 2018; `www.naseprogram.org`), a complete framework of didactics of Astronomy that allows to address all the topics in Astronomy, Astrophysics, Astrobiology and Cultural Astronomy.

Evaluation of Impact: After training a teacher on this approach, it is important to evaluate the impact of the activities. It is well known that if a teacher or a professor is not enthusiastic and does not have the appropriate knowledge, it will be very difficult to apply the activity in the classroom.

This evaluation was made through Satisfaction Surveys, and the intention was to answer questions, such as, "how useful are the activities", "how easy is it to implement the proposal in class", and "how good is the methodology?". In this way we explored the perception of the participants to a teacher-training program based on low-cost materials. In all cases, the answers were very positive, over 80% of satisfaction (see Figure 2).

Impact in the classroom: The other main topic is the real use of materials and resources and this exploration is carried out using a simple form to detail the evidence of the use of activities.

After positive results from the evaluation of the proposal, we revised our ideas about teaching Astronomy, and asked ourselves if the hi-tech and high-cost technology is really a need at the time to transmit Astronomy concepts in a classroom?

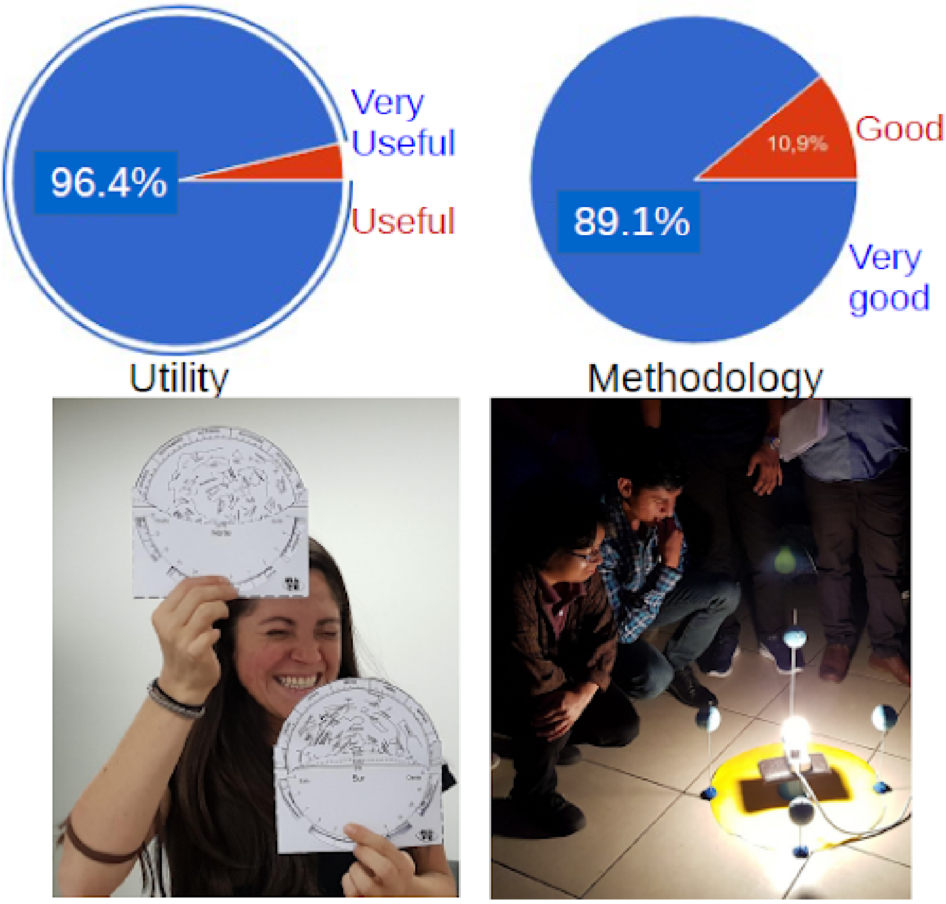


Figure 2: Satisfaction Survey results: average of evaluation of Utility and Methodology.

The low-cost, low-tech tools and resources are not correlated with low-quality education in astronomy. Using different approaches and upgrading contents, the proposal is useful not only for primary and secondary and high schools classes, but also in colleges.

The methodology based on learning by doing and using low-cost materials helps to understand concepts and contents, produce a perdurable knowledge, helps face more complex topics, ensures inclusion in economically disadvantaged audiences and much more!

Reference: Ros, R. M. et al, 14 steps to the Universe, Rosa M. Ros and Mary Kay Hemenway. Eds, Albedo-Fulldome, Spain, ISBN: 978-84-15771-46-3, 2015.

Development of Student's Planetarium for the Teaching of Astronomy

Speaker: Tan Hoe Teck, School of Science and Technology, Singapore

A home-made planetarium is a STEM project for presenting educational and entertaining shows about astronomy and the night sky, or for training in celestial navigation. The design that I am proposing is a 6-meter diameter dome, which can accommodate about 15 students comfortably at any time. Having the dome to conduct Astronomy Lessons reduces the need to have a perfect weather all the time for stargazing, which is a rare event in light polluted cities. The main advantage is student engagement: hands-on construction, planning and implementing a planetarium program. Besides the low cost and portability, the home-made planetarium can encourage sharing of ideas, problem solving and creativity amongst students.

Talk link: `https://youtu.be/alAKugM0ax4`

The design[1] that we are proposing is a 6-meter diameter dome, which can accommodate about 15 students comfortably at any time. Having the dome to conduct our Astronomy lessons reduces the need to have perfect weather all the time for stargazing, which is a rare event in light polluted Singapore night skies. The key parameter for successful learning is student engagement.

Hands-on Learning: Adoption of hands-on learning for the design, purchasing and building for the student leaders. The topics include geometry, cost benefit analysis, sewing, electrical wiring, and ventilation system designs.

Student Agency: Student teachers have to plan and implement an interesting Astronomy program for the audience / participants. The student teachers can plan their planetarium programs according to different themes (e.g. seasonal skies, planetary hopping, deep sky objects, stellar evolution etc.)

Immersive education for participants: Student participants will be engaged in Astronomy storytelling, engaging their senses (light, music, sound, temperature) in a simulated stargazing event even during the daytime.

Low Cost: The low-cost and portability of the Planetarium are not its only advantages: it is a student self-assembled planetarium that can encourage sharing of ideas by students, troubleshooting and creativity among students. In terms of pedagogy, such an engaging environment is ideally suited to a project-based learning (PBL).

[1] Brozis, Mirosaw and Widerski Kamil, 2018. Students' planetarium. Phys. Educ. 53 035029.

IAU-NASE Workshop in Korea

Speaker: Song In-Ok, Korea Science Academy, KAIST, South Korea

In South Korea, the NASE course first started this spring 2021. There are various approaches to teachers' training courses in our country and the NASE workshop is one important way to make comprehensive programs for all levels of training courses. Each has a different character and expectation, and the NASE program is expanding our training course to comprehensive programs at various levels. The lecture on astronomy covers most areas of basic astronomy and the hands-on session with materials that students can easily access. In addition, the organizational operation and philosophy of NASE are expandable and sustainable in their countries, so it will be helpful not only in astronomy perspectives but also in learning organizations.

Talk link: https://youtu.be/VNAmw-5dTXQ

There are various approaches to teachers' training courses in our country and the NASE workshop is one important way to make comprehensive programs for all levels of training courses. There are various teacher education programs in Korea. All teachers must have an official certificate to work at the school and the government controls the number of teachers in each province or city. Teachers can optionally receive various training courses according to their interests while working. There are two kinds of training courses, 1) professional driven by the astronomical society which is short and periodical, 2) amateur driven by amateur astronomical society. The training conducted by amateurs is also open to the general public as well as teachers. As NASE is introduced to our country, additional training methods have been created and will be comprehensive.

Each program of teacher's training is explained in detail and introduced in the NASE program. The NASE program was conducted online. It was first run in Korea in January of this year, and the second one was organized in July. If it is held again around January next year, all 10 workshops will be conducted. Most of the participants were high-school teachers, and about 20 teachers per workshop participated. It was supposed to be offline for 2-3 days, but it has been divided into 3 workshops and conducted for one year. Most of the local teachers are in science high-schools and science-gifted schools because every major city has science high-schools. It is expected that the workshop contents will be spread through them as bases.

NASE highlights:
1) simple and variety activities,
2) hands-on and activity-oriented,
3) communication, sharing and development of thoughts,
4) philosophy of the sustainable system.
Of course, the main power of NASE is the activity-oriented teaching style in our country and another point of view for the same content. It should be noted that communication and

sharing is also the key point of NASE. For example, since English is not our native language, an interpreter was needed. It is well facilitated with pre-translated powerpoint presentations used by instructors. Finally, organizing training sessions in the future makes the program expandable and sustainable in the country.

References:

- Astronomy Education around the World, NAEC Summaries 2020 (https://www.haus-der-astronomie.de/oae/worldwide)
- Gayab Yeol education program, private communication
- KASI teacher's education program, private communication

Understanding Space Travel

Speaker: Corina Lavinia Toma, Tiberiu Popoviciu Computer Science High-School Cluj-Napoca, Romania

Astronomy means many difficult notions and the teacher must know the power of understanding of a child and to make space for real empathy and creative solutions. To achieve this the teacher must use intuitive models and experiments. I present a project achieved with my students about a travel in our Solar System. Why do we have to travel at first in a circular orbit? What is an escape velocity? What is a Hohmann transfer orbit? What is a launch window? These are some of questions the project answers. After many years of teaching I realize that most important are not the formulas, not the problems solving, not to use very sophisticated devices but to make students imagine, to see or to visualize, using simple objects and if it is possible the objects they have in the classroom.

Talk link: https://youtu.be/7jmOJlrtCvc

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From the first successful orbital launch of Sputnik 1 mission on 4 October 1957, space travel has seen an unimaginable development. But such a journey means a lot of technology, many laws and physical principles, different types of trajectories in comparison with those on the Earth, only one fuel station at the departure and some "science tricks" to increase or decrease the spacecraft speed, to get rid of the gravitational influence of the Earth or to travel huge distances with minimum energy consumption, etc. To catch students' attention, videos, pictures, and articles about Huygens-Cassini Mission (https://solarsystem.nasa.gov/resources/11776/cassini-trajectory/) and science news about Rosetta mission were presented.

At first students were acquainted with scientific terms and principles and this was done using simple and intuitive models and hands-on activities. The students were told that the initial rocket trajectory is a curve because the velocity of the rocket has 2 components: a vertical one and a horizontal one. The true trajectory is not a parabola, but a part of an ellipse with the Earth as a focus. As an experiment, the students threw a ball in an oblique direction and filmed the movement and then they could study the parabolic trajectory. After that, they compared this type of trajectory with an elliptical one. In space the orbit is a balance between the force of gravity and rockets' tendency to move in a straight line. Because the distance to the Earth oscillates, the trajectory becomes an ellipse.

The students were amazed at how easily an ellipse with a piece of chalk and a string can be represented (see Figure 1). They chose the distance between the foci and so the drawn ellipse had different shapes. If the distance was 0 then the ellipse became a circle. Thus, the students easily understood the quantities that appear in the ellipse equation and its eccentricity. On each orbit, a spaceship has another speed, so to move from one orbit to another it must use propulsion systems to change speed. This means an orbital manoeuvre. On the other hand the

 

transfer orbit from one orbit to another is a Hohmann orbit (half an ellipse) and in order to travel on such an orbit, the spacecraft must change its speed twice: at the beginning and at the end.

Using Newton's laws, the students calculated all velocities of the planets on their circular orbits from the Solar System, all escape velocities and then the velocity variations for the Hohmann transfer orbits. On a Hohmann ellipse, the fuel consumption is set to minimum because this is where the changes of kinetic energy are smallest. When a spacecraft passes from a planet to another the configuration of the two planets in their orbits is crucial. The destination planet and the spaceship must arrive in their respective orbits around the Sun at the same point and simultaneously. This requirement for alignment gives rise to the concept of launch windows. Thus, the students understood that a spaceship cannot travel directly to a planet on a rectilinear trajectory. Finally, they calculated all the required orbital radii, velocities, and velocity variations and then developed a software that modelled interplanetary travels using the Hohmann trajectories from one planet to another [1]. Through it the students could analyse orbital manoeuvre velocities and necessary travel times between planets.

How to understand what is a fly-by (a slingshot or a gravity assist manoeuvre) in space without knowing what it means as a relative movement and how to increase or decrease the momentum of one body by colliding with another body? The students made experiments with collisions between balls with different masses, which were thrown in different directions and with different velocities. An interesting example was to let a tennis ball and a basketball fall at the same time like in Figure 2. After the collision with the floor, the tennis ball gained a higher momentum than the basketball and had a much higher speed and as a result reached a height much higher than the height from which it fell. This explains the fact that a spacecraft can save fuel and can be "powered", if it passes by a planet or another celestial body with a large mass. This experiment is inspired by the NASE course, where it was used to explain the simulation of a supernova explosion [2].

The most important thing is to make students understand that a computer is a tool that helps them calculate more easily or simulate a physical process, but if they do not completely understand the important phenomena, they cannot program and cannot become authors of valuable software. In the presented project it has been proven that the explanation and the understanding of space mechanics concepts are easier through simple experiments, intuitive examples or models and the using of cheap materials. Why is it so important to do this? Some answers are as follows: the students are eager to do hands-on activities; they like to work together and to find some answers alone; they do not forget what they see and experience. The students can create a software or use a ready-made one only after they understand very well the necessary new concepts and physical phenomena.

References:

1. ICT in Science Teaching, Space Travel, page 60, https://www.science-on-stage.eu/sites/default/files/material/istage1_en.pdf

2. 14 Steps to the Universe, page 115, http://sac.csic.es/astrosecundaria/en/cursos/formato/materiales/libro/llibre_angles.pdf.

The Low-Tech and High-Quality Correlation in Astronomy Education

Speaker: Breezy Ocaña Flaquer, San Diego State University, USA and Gabriela Flaquer, GenerAcciones, Dominican Republic

A Low-Tech Approach (LTA) to astronomy is highly beneficial for teacher training since the amount of technical knowledge and skills required can be intimidating. Regardless of the teacher's background, LTA in astronomy has an enormous impact in breaking down walls and making science fun, interesting and approachable. According to teachers from the Dominican Republic and the USA, two countries with different education systems and approaches to technology, LTA has been useful. To clarify, LTA does not mean low standards or low expectations. We have maintained a high-level of technical concepts and skills training, while providing hands-on materials and creating small learning communities through social media and WhatsApp, which combined, serve to boost confidence, maintain engagement, and provide platforms for clarifications and deeper levels of understanding.

Talk link: https://youtu.be/4dWwwH7E-34

A Low-Tech Approach (LTA) to STEAM education in general, and Astronomy education in particular, can be highly beneficial for teacher-training. An element that teachers sometimes find intimidating in these subjects, is the amount of technical knowledge and skills required. Motivation and positive relationships are key factors in attracting people to new areas of learning. In this sense, our experiences with didactic training in astronomy have had an enormous impact in breaking down walls and making science seem fun, interesting and approachable to teachers that otherwise might be intimidated by higher tech environments.

Modern Astronomy is a science that depends completely on technology. In some cases, it uses the technology already available, and when this is not available, it also develops technologies that are then used by the general public. But when we refer to astronomy in education, we need to start with the basics of astronomy - as done by ancient astronomers - where it does not necessarily depend on technology, but it is still able to reach new levels of knowledge. We need to learn how to observe our surroundings, to pay attention, to ask questions - just as it was done when astronomy began being a science.

LTA does not discard the use of a technological approach, but LTA brings many advantages. It allows a wider audience to participate in the understanding of the subject with a more hands-on and experiential approach, which also makes the learning accessible to any socio-economic level. Schools that have the capability of buying equipment, can also take advantage of LTA, which benefits students in so many ways. For example, they could develop their own tools, which facilitates another level/area of learning besides astronomy. Due to the approach involving students, it also creates an even deeper understanding of astronomy itself. Moreover, the fact that the students not only understand the topic, but build their own materials does foster creativity, resourcefulness, and the experience and gratification is empowering. This goes hand-in-hand with the United Nations Sustainable Goal[2]: Quality in Education. Another important point is that, although being empowered is important for students in general, it is especially relevant for female students in particular, or students from underprivileged areas. These two points are closely linked with United Nations sustainable Goals, Gender Equality, and Reduce Inequalities.

We have offered didactic teacher training workshops in the Dominican Republic (the Network for Astronomy School Education (NASE) [1, 2] , Galileo Teacher Training Programs (GTTP) [3], and others) all of them offer LTA to Astronomy. The NASE workshop has been the most complete one, with material for astronomy, astrophysics, astrobiology, and cultural astronomy. Because NASE uses LTA, many teachers from different backgrounds and most of them with no experience with technology, were able to take, understand, and recreate the material from the course. After the workshop's conclusion, all teachers shared that the course was useful, with 95% of them saying it was very useful.

Interestingly enough, in the USA we offered the same NASE workshop. The material and the content were exactly the same for both countries. Here, we are including their opinion as a comparison sample, since the teachers in the United States, in general, have more access to technology than teachers in the Dominican Republic. The reaction of teachers was very similar in both countries. In the United States, they all found the workshop useful, with 83% finding it very useful. This means that even if we have access to technology, there is no doubt of how much we can gain, learn, and enjoy when we take a Low-Tech Approach to Astronomy.

[2] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

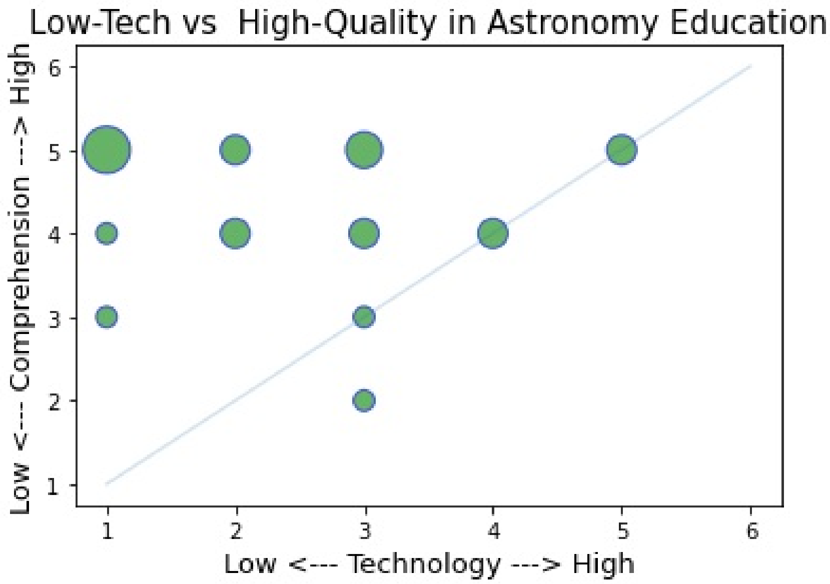

Figure 1: This plot represents the correlation between the level of technology used vs the level of comprehension of the students. The bigger the circle, the more data we had at that point. As can be seen, the biggest circle is the one that corresponds to the lowest technology with the highest comprehension.

We have asked the Dominican teachers, both, who have participated in these training sessions, and other astronomy teachers, for their experience. We can see in Figure 1, that where we have the most amount of data is in the lower-tech range with the highest comprehension of the material. In this plot, the amount of data is represented in the size of the circle; the bigger the circle the more data points were found. The biggest circle corresponds to the point where the teachers considered the technology used was the lowest and the comprehension of the student was the highest. We also note that there was data where the teacher considered the technology to be high and there was a high level of comprehension as well. This does not mean that by using a higher tech approach you do not generate high comprehension, but it does mean that you are not sacrificing the quality of the teaching by using a LTA. It also means that everyone benefits from a Low-Tech Approach, and not only the teachers/students who have already been exposed to technology and do not find it intimidating (which is the minority of the teachers/students).

In conclusion, a Low-Tech Approach does not mean Low Expectations or Low Standards. On the contrary, it means that without sacrificing the concepts and the quality of the materials that will be taught, it is accessible to a wider range of students and teachers who are exposed to and comfortable with technology, and also to the students and teachers with less access and less exposure to technology. Throughout all the activities we have maintained high-levels of technical concepts and skill training. We have provided hands-on materials. And small learning communities were created, which served to boost confidence, maintain engagements, and provide platforms for clarification and a deeper level of understanding.

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Universe Observing Using Locally Constructed Instruments: A Case of Young Astronomer's Briefcase

Speaker: Deodatus Stanley Kiriba, Astronomy and Space Science Association of Tanzania (ASSAT) and Tanzania Agricultural Research Institute (TARI)-Selian Agricultural Research Center, Tanzania

Collaborator: Noorali Jiwaji (Astronomy and Space Science Association of Tanzania (ASSAT) and Open University of Tanzania, Dar es Salaam, Tanzania)

Astronomy links concepts in Science and a basis for understanding Geography. Its historical development provides teaching methods of Science and Mathematics. Hands-on activities provide exciting ways to understand science and guide students into Science and upcoming Astronomy careers being developed in Tanzania. We will describe the application of Young AstronomerŐs Briefcase (YAB) as a tool kit for carrying out hands-on activities for universe observation by using easily available materials around the school and home such as ruler, simplified quadrant and Spectroscope. YAB has been explored and tested through NASE Trainings and thus there is a need to scale-up such a tool kit during Astronomy training across Tanzania.

Talk link: https://youtu.be/wJMiyD3DoOk

Astronomy links concepts in Science and provides a basis for understanding Geography. Its historical development provides teaching methods of Science and Mathematics. Hands-on activities provide exciting ways to understand science and guide students into Science and upcoming Astronomy careers being developed in Tanzania. However, Astronomy training in Tanzania is very limited because it is not offered in Universities, so teachers enter the teaching profession with little understanding of Astronomy and often with misconceptions and lack confidence in those topics as part of the primary and secondary school curriculum.

In 2019 and 2020, the Astronomy and Space Science Association of Tanzania (ASSAT) in collaboration with the Open University of Tanzania organized a three-day IAU-NASE (Network of

Figure 1: Constructing and using the Ruler during NASE training in Tanzania.

Astronomy Schools Education) intensive residential training for 30 primary and secondary school teachers in rural outskirts of Dar es Salaam city, supported by NASE trainers from abroad with the local expert and also build the skills of local trainers to conduct wider local training. Among the several courses that were taught to the participants, one of the topics that was offered was the Young Astronomers Briefcase, which excited the attendees immensely.

Hands on activities:

Young Astronomer's Briefcase (YAB) consists of simple instruments such as ruler, simplified quadrant, spectroscope, simple horizontal goniometer, planisphere, map of the Moon, equatorial sundial, red light flashlight (torch), compass, wristwatch, paper, pencil and a camera. However, of these instruments, the first three, the ruler, simplified quadrant, and spectroscope caught the attention of the trainees due to their simplicity and low price and that it can be made locally and yet allows measuring difficult to view parameters in astronomy. During the training, the trainees were asked to perform different activities as highlighted below:

Activity 1: Use of a ruler to measure angles between any two objects within the classroom and hence a ruler can also be used to measure angular distance between two stars in the sky. The trainees had to cut a cardboard of 20x3cm using a scissor or a cutter, and cut a string of length of 65cm. A photocopy of a centimeter ruler was pasted on the cardboard using glue. Each trainee tied the string to the non-flexible ruler (cardboard) such as to set the string to a length of 57cm. To measure the angular distance between two points in the classroom (or two stars in the sky) they were observed with the end of string almost touching the cheek just below one eye so that each centimeter on the ruler becomes equivalent to 1 degree of angular separation between the two point or stars (i.e., 1 cm = 1°). The trainees were able to understand why it is not possible to measure distances in the sky and instead can use angles, which can be directly and easily measured (see Figure 1).

Activity 2: In this activity, the trainees were taught to use a simplified quadrant to find the altitude (angle of elevation above the horizon) of the stars. While working in groups of two trainees - one looking through the viewfinder and the other making the readings. To make the simplified quadrant, the trainees were asked to cut a piece of cardboard of 20x12 cm into the

Figure 2: Using the Quadrant during NASE course in Tanzania.

shape shown in the diagram below using a scissor or a cutter. A piece of string of 25 cm length and a stone (or any heavy object) knotted at the end of the string. A prepared photocopy of the angle scale on a quadrant was pasted on the cardboard and two round hooks were fixed on the upper edge. A high object or a star can be viewed from the back end of the quadrant and aligned to be seen through the both hooks so that the position of the string on the quadrant indicates the altitude (angle) above the horizon. Once again trainees were impressed that heights of trees could be measured using the quadrant and by applying trigonometry using the distance to the tree (see Figure 2).

Activity 3: In this activity a simple spectroscope was constructed to display the spectrum of sunlight. In making the spectroscope, the trainees were asked to paint the inside of a matchbox with black marker, then to cut a piece of CD (1/8 of CD) and paste this on the inside bottom of the matchbox (with the recorded side of CD facing up) and make a hole on the other side of the matchbox. Each trainee was asked to use the spectroscope with the sun or the lights of the classroom and hold the open end of the matchbox towards the Sun or the lights and view the image of the spectrum formed through the hole made on the other side of the matchbox. Trainees were amazed that a spectrum could be seen so easily using such an easy construction.

In this view, all these instruments and activities are practical and have been applied in the classroom during the NASE Trainings for primary and secondary teachers in Tanzania. It is expected that the teachers who participated can train their students at their respective schools to make their own instruments and organize instruments in an easy-to-use briefcase. With these activities, students will gain confidence in their measurements, take responsibility for their own instruments, develop their creativity and manual skills, understand the importance of systematic data collection, facilitate their understanding of more sophisticated instruments and recognize the importance of observation with the unaided eye, both in history and today.

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Lessons Learnt from e-Amanar Online Teacher Training through WhatsApp for Sahrawi Refugee Teachers

Presenter: Jorge Rivero González, Joint Institute for VLBI ERIC (JIVE), The Netherlands

Collaborators: Sandra Benítez Herrera and Nayra Rodriguez Eugenio (Instituto de Astrofísica de Canarias), Andrea Rodriguez Antón (Instituto de Ciencias del Patrimonio - CSIC), Fabio del Sordo (Institute of Astrophysics - FORTH), Diego Torres Machado (Brazilian Center for Research in Physics), Eduardo Monfardini Penteado (IAU OAE), Mayte Vasquez (EUMETSAT), Felipe Carrelli (Oswaldo Cruz Foundation), Demetrio Rodrigues (Independent Filmmaker), Alba Fernández-Barral (Cherenkov Telescope Array Observatory), and Sarah Massalkhi (IFF-CSIC)

The e-Amanar pilot provided follow-up capacity building for teachers involved in the 2019 Amanar project at the Sahrawi Refugee camps in Tindouf, Algeria, through their phones via WhatsApp that is efficient to slow internet connection environments. e-Amanar responded to challenges raised by the COVID-19 pandemic in 2020 such as the closure of non-essential humanitarian actions at the camps affecting teachers' continuous education. By providing mobile internet data to 17 teachers we organised a 4-month training using audios, texts and slide images to foster discussion about the universe. The pilot resulted in a very successful asset for the continuous connection with teachers and thus supporting Amanar's long-term goals. In the talk, we will present the pilot's outcomes and lessons learnt.

Poster link: `https://youtu.be/vlsRz4Wvs9c`

In this summary, we present outcomes of the e-Amanar pilot that provided online capacity building to Sahrawi refugee teachers through the WhatsApp platform. The Amanar project [1] is an outreach initiative from GalileoMobile [2] that supports the long-standing refugees of Western Sahara. The Sahrawi refugee situation is one of the most protracted in the world, with refugees living in camps near Tindouf, Algeria, since 1975. Access to basic resources is very limited and UN agencies have identified urgent humanitarian needs [3]. In 2019, Amanar organised a summer program in the Canary Islands (Spain) with Sahrawi children spending the summer with host families there as well as activities in the camps, with 635 children, 66 teachers and 150 people from the general public participating in the project activities [1].

e-Amanar pilot: Amanar responded to the challenges raised in the Sahrawi camps by the COVID-19 pandemic in 2020, such as the closure of non-essential humanitarian actions affecting teachers' continuous education. Thanks to an IAU OAD grant, we organised the e-Amanar

4-month training pilot and provided mobile internet data to the 17 participating teachers. The platform used for the training was WhatsApp, which different educational initiatives have shown benefits as a platform to be used for educational activities in slow internet connection environments [4], including refugee context [5].

To make sure the content was relevant for them, the Sahrawi teachers picked the astronomical topics of the four modules of the training. For each module we relied only on audios, texts, and slide-images, producing all audios and texts in Hassaniya and Spanish. The implementation of each module was done through a 2-week period for teachers to go over materials at their own pace and to foster discussions. During the first week, we presented the theoretical background and in the second week we focused on how to introduce the topic in the classroom using as reference the GalileoMobile handbook of activities [6]. A typical day consisted of us sharing a couple of audios with 3-5 minutes duration, images, and short-texts along with them that would take the teachers 10-15 minutes to go over. We also started discussions and someone from the team was always around the chat to answer any questions.

Preliminary Lessons learnt: At the moment, we are still evaluating the impact of the pilot and here are some brief preliminary impressions: 1) Having a script for implementation of the modules was quite useful, but it was also important to be flexible and react to teachers feedback; 2) We found that it was also important to give some time between modules, for them to not be overwhelmed and to interact as well with topics outside astronomy to engage with them better; 3) Teachers were quite keen on asking questions about general topics in astronomy; 4) They were more eager to participate in discussions about the theoretical backgrounds than the implementation in the classroom. Once the evaluation of the project is completed, we will make the required adjustments to the methodology and materials to continue working remotely with more teachers in 2022-2023 [7].

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Bringing Astronomy to the Students and Teachers using "AppStronomy"

Presenter: Rupesh Labade, Inter-University Centre for Astronomy and Astrophysics, Pune, India

Nowadays we can see the evolution of science and technology worldwide. However, teachers and students in many developing countries are not fully aware of it. Also, they should know how to use this technology in the learning and teaching process. So in this poster I want to share my practices with all of them. I have done some low-cost experiments with mobile applications and used them in teaching and learning astronomy. We basically call it "AppStronomy". They proved to be effective during the COVID-19 pandemic, when students were away from their school laboratories and were missing their regular experimentation. We found these applications to be useful for students as well as for teachers to engage them in quality experimentation at home. Using these low-cost experiments they can better understand basic concepts in astronomy. These experiments are cost-effective and easy to make. We did several experiments using these applications and got good observations.

Poster link: https://astro4edu.org/siw/p54

The basic idea behind the concept of "AppStronomy" was to help students perform basic science experiments at home to better understand the scientific concepts that they learn in school. Low-cost experiments using mobile phone sensors can be easily performed to understand concepts such as light intensity, spectrum, magnetism, electricity, motion, acceleration, gyroscopes, sound intensity, frequency, Doppler effect, SONAR, and many more.

To get better and precise results using mobile applications, the sensors need to be calibrated and it is also important to understand how one can reduce manual errors. For this project I have used the following freely available mobile phone applications: Arduino Science Journal (Google LLC, https://science-journal.arduino.cc/), Phyphox (RWTH Aachen University, https://phyphox.org/), PhET Simulations(University of Colorado Boulder, https://phet.colorado.edu/), Zero Shadow Day by Alok Mandavgane (https://astron-soc.in/outreach/activities/zero-shadow-day/), and Stellarium (https://stellarium.org/).

Sky Exploration Festival, a Different Experience for Students

Presenter: Hassan Baghbani, Iranian Teachers Astronomy Union, Iran

Sky exploration festival is a time to objectify the science of astronomy Iranian Teachers Astronomy Union (ITAU) created this festival in 2013, which has since involved thousands of students. During this festival groups of students camp in nature and spend a day with astronomy leaders. They connect to astronomy combined with geology, biology, literature, art, hiking and sports. The most important and interesting point about this festival is that all of work, management and teaching are done by other students who have learned and experienced it before.

Poster link: https://astro4edu.org/siw/p79

The Sky exploration festival includes astronomy and environmental training. Tenting, observing the sun, photo galleries, info-graphics, making astronomical instruments, working with telescopes, observing planets and the Moon, bird-watching are among the most important parts of the festival. Over the last six years, 6350 students have participated, of which more than 5,500 were girls (see Figure 1). Each team consists of 4 or 5 students and they receive scientific projects every November. Student groups get five months to complete these projects in their school or village/city. Methods and structure of the sky exploration festival can be used now by all of the countries and schools around the world.

The best way to learn is to teach. In Kavoshgaran Festival, all the components of the program are performed by the students themselves (see Figure 2). This method has caused students to read the materials in such a deep way that they can teach, so they have the highest learning efficiency. On the other hand, some students who participate in the festival, try to participate again as a leader in the coming years. In order to gain such an honor, they can also gain the experience of a teacher, while they are students. This method is a kind of talent that has helped to discover more talents than today. Mehr Observatory and ITAU are run by the same talents and have been very successful. This method has also helped to carry out all activities with honor, which has been a great help in reducing the cost of the program.

They need to understand nature: These days the contact of children with nature and the planet is so limited that many students do not understand the connection between the excitement of spending a night in a tent. A night with classmates in nature and inside a tent is a sweet experience, held at the Sky Explorers Festival, which received the highest score by the participants. Also, the environmental problems that are increasing year by year on our planet is a serious danger and shows that we are performing poorly in implementing the geographical lessons, and when we correct this method. And in this case, a part of the geography lesson is to go to nature and touch it.

Figure 1: The girls at the festival.

Figure 2: Kavoshgaran Festival.

Finally, students understand being away from home for a day, and have the opportunity to find their own needs independently of the parents and it helps to better appreciate their parents.

Media highlights: https://mond.ir/module/news/21470, http://mond.ir/module/news/41407/.

Development of a Solar Demonstrator Projected in the Classroom Modified from the NASE Demonstrator

Presenter: Akihiko Tomita, Wakayama University, Japan

The diurnal motion and the different movements of the Sun throughout the year, which are studied in elementary school, are things that can be observed in daily life, but are not easy for students to understand. The teacher training program, NASE, has developed an excellent teaching material called the solar demonstrator, that can be easily constructed. By attaching a flashlight to the arm of the NASE solar demonstrator and projecting it onto the ceiling and walls of the class room, an elementary school teacher Yumine was able to show the movement of the Sun to the students in the entire classroom. The students and their teacher were able to observe and enjoy the movement of the virtual Sun throughout the classroom.

Poster link: https://youtu.be/W8CxTawqHXs

The teacher training program, NASE, has developed an excellent teaching material called the solar demonstrator, a paper-craft tool for explaining the movement of the Sun, that can be easily constructed. The teacher, Yumine, originally practiced projecting a simulated Sun on the walls and ceiling of the classroom by attaching a flashlight to an equatorial mount for the telescope. This is a very good teaching tool, but an equatorial mount is a rather large piece of equipment. It is also a specialized piece of equipment for children. He then used the NASE solar demonstrator as an equatorial mount specialized for the movement of the Sun, which led to the development of this new teaching material.

The students, along with the teachers, could observe the simulated movement of the Sun depending on the season throughout the classroom. The feedback from students was very positive; "The locations of sunrise and sunset are different depending on the season." "In summer, the days are certainly longer. I was able to confirm this once again." "In winter, the altitude of the Sun is so low. Also, the Sun's rays are at an angle, so in winter, the sunshine comes through the windows well." "In summer, near the time of sunrise and sunset, the northern wall is also exposed to sunlight."

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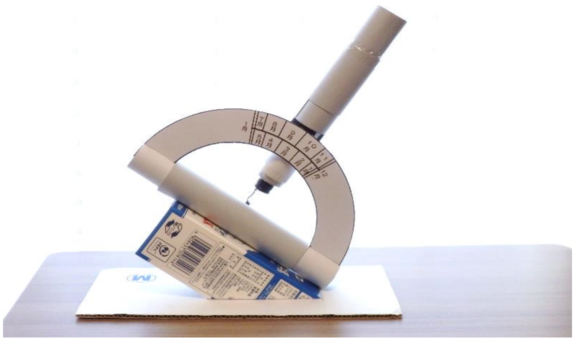

Figure 1: The newly devised solar demonstrator based on the NASE solar demonstrator. A bright flashlight, the model Sun, is attached to the arm which indicates the meridian in the sky. This photo shows an example of a latitude of 35 degrees north in Japan.

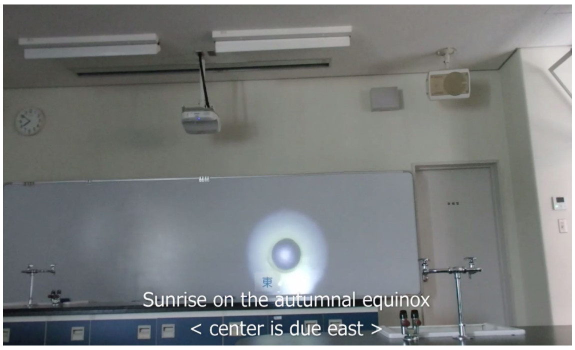

Figure 2: The diurnal motion of the model Sun projected from the flashlight on the wall and ceiling of the classroom is simulated by the motion of the arm. The photo shows the sunrise on the autumnal equinox day when the Sun rises from due east.

Impression of Astronomy in Persian Culture and History Inspired by Poems of Khayam and Attar

Presenter: Mahdi Rokni, Astronomy instructor at SINA, Iran

Collaborators: Fatemeh Abdoust, Maryam Hadizadeh, Melika Gonbadi, Reyhane Johari and Jalil Allahkhani Topkanloo (Iranian Teachers Astronomical Union (ITAU) members)

There is a huge connection between science, nature and literature with Persian culture in Iran. If you look into Iran's history and search in many places or read Persian poems you can find a lots of astronomy knowledge. Some of Iranian great poets have been also astronomers such as Khayam or they became mystics like Attar Nishaburi. This is about stories and people who lived in different ages or lived at the same age together and they have had a huge impression on Persian culture. it can also separate science, literature and mysticism from each other.

Poster link: https://astro4edu.org/siw/p57

Ghias al-Din Abu al-Fatah Omar ibn Ibrahim Khayyam Neyshabouri (Omar Khayyam) was a persian polymath, mathematician, astronomer, philosopher, and poet. In this study we review his personal life and achievements, relation between his poetry and astronomy. We also study

The Mausoleum of Omar Khayyam is a modern monument of white marble erected over Omar Khayyam's tomb located in Omar Khayyam Square, Nishapur.

Rubáiyát of Omar Khayyám is the title that Edward FitzGerald gave to his 1859 translation from Persian to English.

the architecture of his tomb. Omar Khayyam (1048-1131) was born in Zebar-khan in Mamorie village south of Ghadamgah- Neyshabur. He was skilled in politics, mathematics, philosophy, theology, mysticism, astronomy and literature.

Omar Khayyam knew the science of trigonometry and created Khayyam triangle, also known as Pascal triangle. He used the sphere and poles of Earth created by Abu-Ali Sina and the book "Remaining Signs of Past Centuries" by Abu-Rayhan al-Biruni to design Jalali calendar and also measured the length of a year 365 days and 5 hours and 48 minutes and 46 seconds; his calendar was precise; just 1 second every 30 years.

Omar Khayyam was a disciple of Abu-Ali Sina who was a disciple of Aristotle and Plato. Plato believed in idealism and rejected evidence of negation of God according to rationalism. Omar Khayyam not only believed that God is the creature of the whole universe but also believed in the power of nature in human destiny; He was a naturalist.

As Omar Khayyam was a disciple of Abu-Ali Sina and his philosophy stressed the impermanence of the world so he insisted on being happy. As he was an astronomer, astronomy had a huge influence on his poetry. Omar Khayyam's tomb was first built by order of Reza-Shah in 1934; 29 years later Hushang Seyhun, a very famous and experienced architect designed a new tomb for Omar Khayyam which was based on his thoughts. His tomb has a tower with a height of 32 meters with 10 bases which are represented by two-digit numbers. The court symbolizes the sun from the inside and the wine cup from the outside.

References:

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Discussion summary

We thank everyone for the lively discussion following this session. Below we summarize some of the questions and answers.

Tan Hoe Teck was asked about the time it takes to build the planetarium. He answered that although the research paper is available, it is challenging to obtain all the parts simultaneously, and mistakes can happen. Generally, it took about 6 months, wherein each month, one session of 6 hours was carried out. He was also asked how the students have the time to do all this work? He clarified that the students spend their after-exam period to build this planetarium, as an extracurricular activity. About 50 members of the Astronomy Club were involved in the planning and construction.

Song In-Ok was asked how the content of the NASE course/workshop was evaluated effectively. She answered when the contents are new approaches, it inspires teachers a lot and that NASE has many creative approaches with low-tech. Song In-Ok was also asked how one can apply these activities into the school curriculum. She mentioned that it might not be in the school curriculum but that NASE programs are developed to fit into the content of classes and can for example, be used as demonstrations in the classroom. She was also asked about the certification in Astronomy in Korea and she clarified that teachers can have their certificate in the department of education of Earth-science. The final comment was that more NASE courses should be locally conducted so the benefit of its low-tech approach can also be seen by the governments.

Breezy Ocaña elaborated on the point that "low-tech does not mean low comprehension". Astronomy is a science that depends on technology, this might give the impression that if we do not have the technology we cannot teach "good astronomy". This is far from reality, including a low-tech approach is beneficial. It takes the student back to the basics allowing a deeper understanding, a more hands-on approach and they are the protagonists of their own learning process. This can also be seen in the result of the survey we carried out. Breezy was also asked if apart from the overall technology exposition, the socioeconomics were similar in the two cases in the Dominican Republic and the USA. She responded that for most of the teachers the reality was very different, with less access to education, information and of course, technology.

Beatriz García was told that using a rubber band to illustrate the expansion of the universe is very clever and thanked for sharing the idea. This experiment is an analogy rather than a "proof". Also, with analogies, we need to be very cautious and aware of their limitations. Do you explain those to your students? She clarified that yes, we can consider the experiment an analogy, the universe is not a rubber band, but the result is the same. You need to show without any doubt that the galaxies are driven apart by the expansion. Some demonstrations are not easy in the classroom, you need a model and to explain how to verify the model.

Beatriz García was asked about accounting for local cultures in the NASE workshops. She responded that in principle, the most important thing is that the NASE courses are given in the local language, this fact not only includes the translation from the original texts but also to adapt the language to each community. There is a complete workshop about Cultural Astronomy, and the content may change for each country. Please visit `www.naseprogram.org`.

Naked-eye Astronomy

Session organisers: Anna Sippel, Office of Astronomy for Education/Max Planck Institute for Astronomy/Haus der Astronomie, Germany and Tshiamiso Makwela, University of Cape Town, South Africa and Office of Astronomy for Education, Germany

Session overview

Naked-eye astronomy invites us to enjoy and learn about the night sky without any optical aid or a telescope. In theory it might seem easy to simply look up and dive into the world of stars, but in practice is often difficult to achieve. Some of the contributing difficulties include: light pollution, night sky observations cannot be carried out during regular school lessons, and our modern world provides us with many distractions preventing us from looking up at all. As such, this is one of our main tasks as educators & practitioners, to encourage and motivate students to overcome this first step. In addition, observing the night sky with no tools is an activity that many professional astronomers have little experience in. However, learning about the night sky can help us overcome our fears of the night, and unlock the wonders of the sky.

This session guided us from theory to practice and application of various aspects that enable us to plan projects related to Naked-eye astronomy, and our enthusiastic speakers shared very valuable experiences. Various possibilities were presented to provide students as well as the public, with different backgrounds and interests an invitation to the night sky. This can be via the use of a mobile phone app to get started until the use of a planisphere is learned, night sky observations at observatory or historical sites or even in a café in a city.

Astronomy Diaries and their Effect on Students' Understanding and Attitudes

Speaker: David R. Gozzard and Marjan G. Zadnik, University of Western Australia, Australia

Traditional lectures have been shown to have limited effectiveness in conveying unfamiliar concepts. To increase student engagement and understanding of concepts students in an introductory astronomy course were instructed to record and analyze their naked-eye astronomical observations over a semester. Pre- and post-course evaluations including an astronomy concept diagnostic test and an attitudes survey were used to determine the effect this activity had on students' learning. The results suggest that observing diaries are a positive learning experience for the majority of students. However, the diary task must be carefully integrated into the course content to derive maximum effectiveness.

Talk link: https://youtu.be/JS2Bcj-QKmU

Setting students the task of recording their own regular observations of the night sky, and getting them to analyse and reflect on what they observed, can help students to learn basic astronomy concepts that traditional lecture-style classes often fail to convey. When used properly, astronomy diaries help to promote students' engagement with the course material, allow students to express their own creativity and preferences, and benefit students who struggle with exam-style assessments. However, the diaries take a lot of effort on the part of both the students and teachers, and must be weighted accordingly in the marking scheme. For maximum benefit, an assessment involving astronomy diaries should include a set of compulsory observations, guided observing opportunities, early feedback on students' efforts, and an emphasis on analysis and discussion of their observations.

Introductory astronomy courses have proved very popular with students not majoring in science, technology, engineering, or mathematics degrees needing to fill the science portion of their general education requirement. As a result, such "astronomy 101" classes have become very important because they are often the last formal science education a student may receive, and so the last chance to influence their science knowledge, literacy, and support for science.

Students' understanding of key phenomena, such as the cause of seasons and phases of the moon, are fundamental to understanding other scientific concepts, and making sense of new research findings reported in the media. However, traditional methods of teaching (i.e., lectures and exams) are not as effective as we would like for conveying new concepts, and are particularly ineffective when students come to a class with prior, inaccurate, conceptions about how their reality works. Students are capable of reproducing what they have been told, but they have not internalized the information and understood the concepts, and they cannot apply what they have learned to new situations.

'Observation journals' are commonly used for teaching and assessment in fields such as biology and conservation. Students are instructed to keep these journals to record, in detail, what they see in the field, in order to hone their observation skills. Observation diaries have also been advocated for use in astronomy education as a way of increasing student engagement, and improve their understanding by encouraging them to see astronomical phenomena for themselves.

We gave our students the task of keeping a diary of their own naked-eye astronomical observations over the course of the semester. As well as assessing the presentation of the diaries and students' reflection and analysis of their observation, we also used a pre- and post-course test to assess how students' understanding of astronomy concepts improved, as well as how their attitudes to astronomy and science changed. By comparing the results to a similar astronomy unit that did not include the diary task, we were able to analyse the effects the diary task had on students' understanding and appreciation of astronomy.

Results: We found that, at the start of the semester, there was a large disconnect between our students' appreciation of 'science' versus 'astronomy'. On average, our students believed that astronomy was both more difficult and less useful in their lives. By the end of semester, students' positive attitudes towards astronomy had improved and come closer to par with their attitudes towards science in general, more so for the class with the diaries than for the class without the diaries.

Many students put a large amount of effort and creativity into their diary, suggesting the diaries did stimulate greater engagement with the assessment task. A number of the diaries included very good illustrations or other artistic flair. Some students chose to blog their observations, and two even chose to present multimedia diaries using PowerPoint.

The results for the astronomy concept tests show that the class that used diaries did experience a greater improvement in their understanding of the concepts, but the size of the effect was smaller than hoped. We also compared students' marks for the diary assessment with their marks for the final exam and found very weak correlation, which indicates that tasks such as the astronomy diary may suit some students who normally struggle with traditional assessment methods.

Using astronomy diaries in the classroom: Based on our research and the results of other studies on astronomy diaries and other forms of observational journal assignments, we have several recommendations for how to effectively implement an astronomy diary task.

Setting the task – Show students examples of previous diaries to indicate what is expected of a good diary. Allow students to choose the format of their diary, in order to allow them to exercise their creativity, as long as their chosen format is able to convey the necessary information. Pick a free astronomy app (the authors used Stellarium) to help students navigate the night sky, and show them how to use it. Provide students with the marking rubric at the start of the assessment. (An example rubric is shown in the table below.)

Guidance – Set compulsory observations that the students must complete in the first four weeks of the semester. Recommended compulsory observations are: 1) observe the position and time of four sunsets (or sunrises), 2) four observations of a planet moving against background stars, and 3) four observations of the Moon on consecutive days. Run a teacher-guided observing session with the students. This must be done as early in the semester as possible because students are resistant to changing their observing practices once they have established a routine.

Early feedback – At the end of the compulsory observation period, give feedback and an early or indicative mark to the students to help them adjust their observing or reporting practices. Discuss the diaries and observations in class.

Marking – Emphasize the need for reflection and analysis of accumulated observations in the marking in order to guide students towards deeply considering how the sky changed over the course of the assignment and the pattern that emerged. Encourage students to draw diagrams to explain the reasons for the phenomena they are seeing. The assessment should be appropriately weighted (20+% of the course total) to reflect the level of effort students should (and do) put into the task.

Assessment scale: 5 - excellent, 4 - very good, 3 - satisfactory, 2 - acceptable, 1 – unacceptable, **0 – not done**

Diary clearly organized, i.e. used a consistent or systematic method of reporting observations	5	4	3	2	1	**0**	Diary disorganized
Interesting diary, e.g. contained images, photos, drawings, alt/az bearings	5	4	3	2	1	**0**	Boring diary. Did not contain:
Considerable effort, i.e. many (more than 10) detailed observations spread over semester. Compulsory obs done.	5	4	3	2	1	**0**	Very little effort, rushed with few observations.
Included reflections/comments on observations and analysis of data.	5	4	3	2	1	**0**	**No comments or analysis – just data.**
Included discussion of the analysis and conclusion drawn.	5	4	3	2	1	**0**	**No discussion or conclusions**
TOTAL (/25)							

Students' Mental Models about the Apparent Motion of the Sun and Stars

Speaker: Hans Bekaert, KU Leuven, Department of Physics and Astronomy and LESEC, Leuven, Belgium

We administered the AMoSS test with 12 multiple choice questions, which focus on distinctions between different aspects of the apparent motion of the Sun and stars, to 16-17 years old students of 6 Belgian secondary schools (N=410). We also asked them to explain their choices. The analysis of their answers reveal that, despite instruction, most students only demonstrate a rudimentary understanding of the apparent motion of the Sun and stars for different locations of the observer and different times during the year. On top of that, there is a clear distinction between the replies for the Sun and stars. Thanks to the classification system we have developed to categorize the explanations, we are able to identify different student mental models about the apparent motion of the Sun and stars.

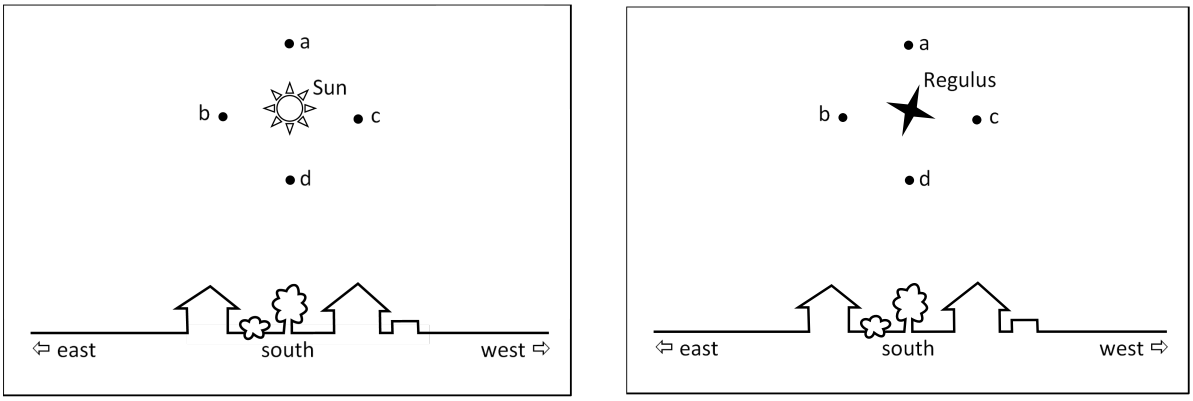
Talk link: `https://youtu.be/XiOLWjgEioE`

Problem Statement

Although the apparent motion of the Sun and stars is part of our daily life, research reveals that many students have alternative conceptions about this phenomenon (Slater et al., 2015; Plummer, 2009; Vosniadou & Brewer, 1994; Trumper 2001). However, only little is known about students' understanding of similarities and differences between the apparent motion of the Sun and stars. This study focuses on these differences and similarities. We therefore designed a framework to disentangle different factors that influence the apparent motion and to compare the different aspects for the Sun and stars in relation to the time of the day, time of the year and the observer's latitude. For each factor we designed test items, also inspired by literature. This resulted in the AMoSS test[1] (Bekaert, 2020) with 12 multiple choice questions: 6 questions about the Sun and 6 parallel questions about the stars. For 6 out of 12 questions, we also asked students to explain their answer. Figure 1 shows the first two questions of the AMoSS test as an example of two parallel items.

We administered the test to 410 high school students (16-17 years old) during a science class. Based on the multiple choice answers, the mean score for all participants on all questions was M = 45%, SD = 18%. On average the six Sun questions (M = 55%, SD= 24%) were answered more correctly than the six star questions (M = 36%, SD = 21%). Bottom up from the student explanations, we have designed a classification system to categorize these written explanations. This categorization system should give us insight into the students' mental models about the apparent motion of the Sun and stars. In this paper we report on the mental models we have

[1] The work was co-funded by the Erasmus+ program of the European Union (2020-1-IT02-KA201-079528).



Question (a): On March 21st, an observer in Brussels sees the Sun in the south high above the horizon as shown in the figure. Where does this observer see the Sun one hour later?

Question (b): On March 21st, an observer in Brussels sees the star Regulus in the south high above the horizon as shown in the figure. Where will this observer see Regulus one hour later?

Figure 1: Two corresponding questions: (a) The apparent motion of the Sun. (b) The apparent motion of stars.

identified, based on the classification of the students' written explanations and a statistical analysis (Latent Class Analysis) of the multiple-choice answers.

Students' mental models

For a more detailed understanding of how students explain the phenomena of apparent motion, we try to identify their underlying mental models. Although there is no agreement about the exact definition of a mental model, in general, the term refers to the internal representations that people form of the outside world through their interaction with it. Bao (Bao, 1999) put forward his definition of mental models by considering other descriptions in the literature. According to him, mental models are "*productive mental structures that can be applied to a variety of different physical contexts to generate explanatory results*" (p. 13). Corpuz and Rebello (Corpuz & Rebello, 2005, 2011) defined a mental model as "*students' way of understanding a certain physical phenomenon*", which can also be unseen physical phenomena. Mental models may contain contradictory elements and are generally different from scientific models, which are accepted as valid if they are coherent, stable, and experimentally validated.

A latent class analysis of student answers on the different questions together with our classification scheme, allowed us to identify four specific mental models that students use to explain different aspects of the apparent motion of the Sun and stars. Apart from these models, we realized that many students are very incoherent in their explanation and do not show consistent reasoning to explain the apparent motion of the Sun and stars.

Administering the Apparent Motion of the Sun and stars test (AMoSS) with a group of Belgian students of the fifth year (16/17 year olds) of secondary education (N=410), allowed them to identify several mental models that students use to explain their answers.

In the presentation, the different mental models about the apparent motion of the Sun and stars, will be discussed in detail.

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Inviting Students and Teachers to Look Up!

Speaker: Julie Bolduc-Duval, Discover the Universe, NAEC Canada, Canada

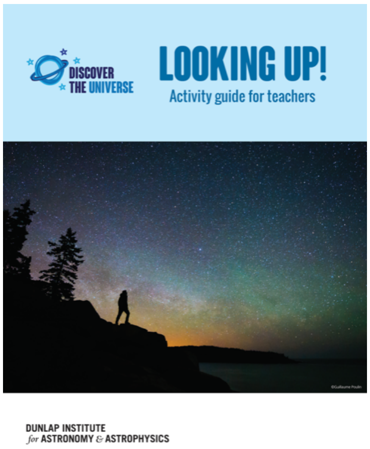
Astronomy is all about observing the sky, but teachers rarely do it with their students. There exist many activities to explore the sky during the day and at night, from a rural area as well as from a city. We will present many ideas which we brought into an educational module named Looking Up! available in English and French. The activities can be adapted to many grade levels and require very simple materials. We strongly believe that discovering the sky allows students to connect with their environment and learn about a lot more than just astronomy.

Talk link: https://youtu.be/62UsFlMMqfI

In our busy everyday life, we do not tend to pay much attention to the sky. We rarely look up, day or night, and most of us unfortunately do not feel a connection with the sky. It is a sad reality since there are many objects and phenomena that can be observed easily, during the day or at night, and from everywhere, whether you live in a city with a lot of light pollution or in a rural area with pristine night sky. We feel it is important to invite teachers and their students to look up to reconnect with the sky and their environment. Spending time outdoors and observing our surroundings allows us to better know, understand and appreciate our environment. And this impact goes beyond astronomy: developing one's own experiences in nature is essential to be connected to the land and the different species that live there.

Educational module *Looking Up*! Observing the sky and the different visible phenomena can be very rich and bring beautiful discoveries for everyone, especially students. We created the educational module Looking Up! with that goal in mind: to enable students and their teachers to discover the sky easily and without complicated instruments. It consists of eight simple activities enabling students to learn more about the Moon, the Sun, the Earth and its motions, as well as the stars and constellations. The activities can be adapted to many grade levels or age of the students. While some of the content connects more closely to the grade 6 school curriculum in many provinces here in Canada, we have adapted some of the activities to lower and higher grades before. We hope you can get inspired by this educational guide and we invite you to adapt the activities to your own reality, especially if you live at latitudes much different than about 45 degrees north. This educational module can be downloaded for free on our website at www.discovertheuniverse.ca/resources. It is also available in French at https://www.decouvertedelunivers.ca/ressources.

Observing the Moon: The Moon is the easiest celestial object we can observe directly and easily. Students could keep a Moon journal for a month to discover its phases. The goal is to observe the Moon as often as possible during a full lunar cycle. Obviously, it will be impossible to observe it every day, since clouds will be present. It is OK: you do not need daily observations



to observe patterns and understand how phases work. Invite them to observe often, day and night. Young (and not so young) people are often surprised when they notice the Moon in daylight for the first time! When the Moon is visible during the day, you can bring balls outside to model the phase of the Moon. By holding the ball under the real Moon, the ball will show the same phase as the Moon. This simple activity allows students to realize that the Moon is always a sphere, and that its phase is simply the result of how the Sun lights the Moon and our perspective here on Earth.

Observing the Sun: While we do not recommend direct observing of the Sun for your eyes' safety, there are ways to study the position of the Sun to notice differences throughout the year. These observations can then be tied to concepts about the Earth's rotation and revolution around the Sun. Students can be invited to study daily or seasonal cycles by paying attention to the position of the Sun over a certain period. An easy way to do this is by measuring the length of a shadow many times in a day and comparing. Another great activity for students is to pay attention to the position of the Sun as it sets. They could draw the horizon looking west from their home and draw the position of the Sun once a week or so to notice differences. If students have access to digital cameras and are up to the challenge, they could take pictures of the sunset over a long period and create a video with all pictures. They might be surprised to realize how much the Sun moves on the horizon between the summer and winter solstices!

Observing the Stars: Observing the stars and constellations might be harder if you live in a light-polluted area. You could still invite students to learn more about the stars using a star finder or a sky map. You could also discuss light pollution and have them measure the light-pollution level where they live. We highly recommend the program Globe at Night (`www.globeatnight.org`), which provides maps of how specific constellations would look under a dark sky vs a light-polluted sky.

Observing the sky is the basis of astronomy and each of us can learn more about the universe simply by looking up more often. Whether in the school yard, in the park or at home, simple activities can be carried out to "live" astronomy instead of just passively learning it. This experience will be even richer for budding young astronomers and will create memorable experiences for all.

Naked-eye Astronomy Projects

Speaker: Shylaja B S, Jawaharlal Nehru Planetarium, Bengaluru, India

I would like to broadly classify them in to day time and night time astronomy projects. In the daytime projects involving the sun, shadow measurements at meridian passage was one of the most successful project. There were a few related to the moon as well. Although the night sky offered very little scope for the urbanites I utilised the passages of HST and other bright (artificial) satellites for a few practical sessions. The most popular among them was with the local radio stations which gradually got converted to Whats App sessions last year. The occultations, conjunctions and meteor showers also offered a good opportunity. I will quote some examples and possibility of exploiting these ideas for the current pandemic era.

Talk link: https://youtu.be/4aOp5QGuWMI

Today, in the era of space age, observing with naked eyes still holds the key to understanding the universe. Thus even before using the digital gadgets, we need to get the basics right and that is possible only by naked eye observations.

The sky watch actually begins in the day observing the sun. However, we will restrict our discussion to the night sky only.

The easiest object to start sky-watching is the Moon, which not only tells about its own motion among the stars but also about the stars in the background. Noting the phases and the repeatability may appear to be a routine thing that loses charm in no time. But finer details like the liberation and the visibility of craters throw challenges. Eclipses, both lunar and solar, offer a great opportunity for naked eye observations - something a camera cannot capture. One of the best examples is the sky brightness measure, which hints at the solar activity in case of solar eclipse and the volcanic dust content in the earth's atmosphere. The gradual emergence of stars in the vicinity of the moon as the eclipse progresses into a pitch dark sky is an interesting to watch and enjoy. The colour of the eclipse moon also is an enjoyable sight. More so if it has a star cluster like Preasepe or the nebulosity of the Milky Way nearby. The penumbral eclipse is another challenge for naked eye observers (see https://apod.nasa.gov/apod/ap161012.html). I recall an elderly man of 80 calling me to check if something was "wrong" with the southern tip of the moon. Having observed the moon for over 60 years he was able to recognise the penumbral shadow.

The orientation of the crescent moon to the horizon varies from month to month and also with latitude. All these offer great opportunities for those with a skill in painting.

More familiarity with the moon and its motion will make one look for occultations, close conjunctions with planets and bright stars. The passage of the Moon through clusters like

Preasepe is an enjoyable sight indeed. This also makes one ponder at the not-so-interesting repeat performances after occultations exactly 28 days later.

High tides are well-known along the coast; the periodicity associated with it is also known to fisher folk. Few students monitored the height of the tides through the month. They were able to identify the effect of perigee and apogee even when the events did not coincide with the new or full moon. This was one of the most effective ways of debunking the myth of the "super Moon".

One of the challenges faced by all sky gazers is to mark a lunar analemma. The solar analemma is quite simple to achieve. In the case of the moon the figure of 8 will have different orientations throughout the year. This can be best rendered as a hand drawn picture or with images from a very simple aim and shoot camera. (see `https://apod.nasa.gov/apod/ap200507.html`) The other type of objects that attract the naked eye observations are the planets. Here again, the mutual conjunctions and bright stars provide great opportunities. Last year the passage of Venus through the star cluster Pleiades offered a great opportunity. The conjunction in December 2020 when Saturn and Jupiter approached each other with a small angular separation was used to test the detectability of the limit of naked eye observations.

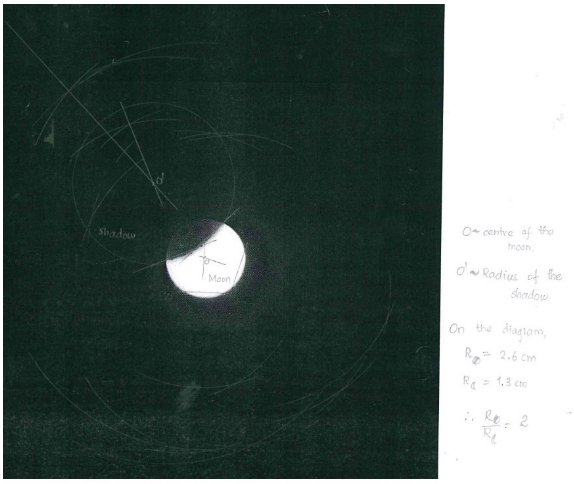
Twilight has always been a delight to watch and enjoy. It is interesting that an estimate of the duration and the richness in colours done 100 -150 years ago resulted in the important deduction of the effect of volcanic dust on twilight. Spending a couple of minutes watching the colourful sunset and twilight can give clues on the volcanic dust content, which renders the sky more colourful and extends it to a much longer duration.

Concepts like heliacal rise and set can be easily understood with naked eye observations. The light pollution, in today's context and the visibility of the horizon play an important role in establishing the sightings of heliacal rising as well as the youngest moon.

Bright comets like Hale Bopp and NEOWISE offer a great opportunity for naked-eye observations. There have been interesting reports of "detachments" - ejection of a knot-like structure in the tail of comets - by naked eye observations in the past. Meteor showers are best enjoyed with naked eyes. The cell phone camera can be of some assistance.

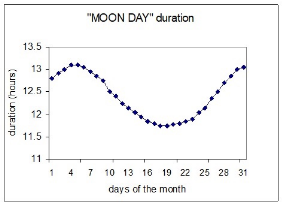
When we try to observe the stars and constellations the challenges are many. The planetariums and sky apps on the mobile phones offer short quick dosages like capsules - a natural, nourishing, vitamin rich dosage should be procured by patient sky watch sessions only. Beginners find it extremely difficult to identify the constellations. More so under a light-pollution free sky. One of the earliest attempts here in Mysore (almost 50 years ago) was with the radio guided tour. The listener would move to his terrace with the radio and just a handy 30cm scale. The dates for these broadcasts would be chosen around the first quarter, so that the moon is available as a guide. This was very effective and achieved a very vast geographical coverage. The purpose of the scale was to guide the listener to the stars around the moon - it would be held at arm's length and the reading would help them identify the star. This kind of exercise would also help in star-count exercises, which can indirectly hint at the effect of light pollution.

After establishing the familiarity with constellations and star charts, one will mature to observe variation in brightness of stars as was done by the young boy John Goodricke 300 years ago.

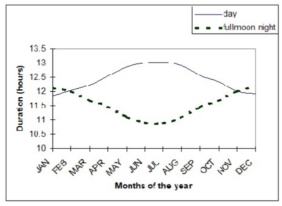


Estimation of the diameters of shadow and moon by Godvin, a student

A simple exercise of observing the rise and set time of the moon throughout the month led to a very interesting discussion in the class room. The duration of the full moon night through the year also generated lot of discussion.



The variation of the "moon day" - interval from moon rise to moonset - in a month



The variation of the duration of full moon night as compared with that of day time.

The drawings and photographs of the lunar eclipse was used by school students to get the radius of shadow and the radius of moon.

This is the age of digital gadgets. Therefore the group calls, chats (the order of the day during the pandemic) serve the sky watch sessions very effectively. We found this especially useful during December 2020 for the great conjunction event.

The artificial satellites are a big problem for sky watch. However we can use them to our advantage. I found the passages of ISS especially useful for introducing the names of the constellations to the beginners. The session would be planned for about 15 minutes to have the ISS passage in between. Thanks to Heavens-Above.com, (Alok.com and Xavier Jubier) the charts could be provided well in advance. The constellations along the path were introduced before the event. The identification would be attested when the ISS arrives - this dot in the sky serves as a pointer. The accompanying audio commentary helps the listener to correct himself if he made any mistakes. The commentary continues after the event to guide them to other constellations. Occasionally even HST would grace the sky for a second session through different sets of constellations. For children it is fun. For adults the accuracy of prediction is a wonder. In any case, this short break from routine drives them towards the sky - an exercise long forgotten.

Promoting of Astronomy through Naked-eye Observation on Heritage Sites

Speaker: Siramas Komonjinda, Chiang Mai University, Thailand

Many Heritage Sites were built based on the knowledge of Astronomy. Without any instruments, people in the past observed astronomical events, recorded and analysed them. They could systematize their observations and find their own astronomical knowledge. In this talk, we will present the work of the Archaeoastronomy Research Group in Thailand. Many heritage sites were built using ancient astronomical knowledge. During every visit visit to these monuments, astronomers observe the Sun, the Moon, and the stars of the ancient people. These engage the interest in Astronomy from archaeologists, historians, and the public. It is promoting local knowledge which made locals interested in Astronomy, both ancient and modern.

Talk link: https://youtu.be/Gl0gB2W0zDY

Astronomy is one of the oldest knowledge of humans. Since hominids started to understand things around them to form the early communities, they observed the Sun, the Moon, planets and stars. They counted the date between each full moon, positioned the Sun of each sunrise and sunset, and checked the position of wanderer stars. For example, a bone found in Thaïs cave, close to Saint-Nazaire-en-Royans, France is a part of a bovine rib engraved with lines that might be related to Luni-solar time record. It is dated back to 12000 years ago. (Portal to the Heritage of Astronomy, 2021)

These kinds of observations create systems of calendar of their own in many cultures. Calendars might be based on Moon phases (lunar calendar), Sun position (solar calendar) or both (luni-solar calendar). Planets may also appear in some cultures, especially those with Chinese influence, i.e. 60-years cycle which is related to the Great Conjunction between Jupiter and Saturn.

Even though these people are naked-eye astronomers, they used many kinds of instruments to observe; from small instruments like a quadrant to large instruments like the monument. Many heritage sites of several cultures were built to support these ancient astronomical observations. Recently, the Chankillo solar observatory and ceremonial centre has been inscribed on the World Heritage list. This is a prehistoric site (500-200 BC) in Casma Valley near the north-central coast of Peru. A thirteen cuboidal tower runs north-south. From the observing site which is 3 km away, the Sunrise could be observed at the gap between each tower. From Summer solstice to Winter solstice, the towers are interpreted as horizontal markers for solar observation (Portal to the Heritage of Astronomy, 2021).

Archaeoastronomy sites in Thailand

Thailand, is a country which well-known in her rich of cultures and natural resources. Many historical sites are popular for tourists, including Ayutthaya (Siam Capital during 14th – 18th Century) and Sukhothai (Capital of Sukhothai Kingdom during 13th- 14th Century). However, the country which was known as Siam is actually a combination of many kingdoms of the past. Until these days, a tourist will find the difference in culture, language, and food between each part of Thailand. These are the heritage of the long history of the descendent of those kingdoms. For example, Lanna Kingdom, which became part of Siam in the late 18th Century was an independent Kingdom from 1262 AD, and Chiang Mai was its capital from 1296AD.

Nevertheless, the cultures were exchanged between these kingdoms and also with the surrounding kingdoms such as Khmer Empire or Pagan Kingdom (presently part of Myanmar) or influenced by China and India. This creates a specific knowledge in many subjects, including astronomy.

In our research, several heritage sites were studied in their relationship with astronomical knowledge, especially those in Lanna and the South-eastern part of Thailand. They are mostly Buddhist monuments related to the 10th – 13th century. These places are not only religious monuments but also used as astronomical instruments.

For example, Prasat Hin Phanom Rung (Phnom Rung Stone Castle) in Buriram, a Hindu-Buddhist temple complex of Khmer Empire which dates back to the 10th century, was restored in the 1970s – 1980s. The sunrise phenomena which can be observed twice a year through the main part of the complex attract people to observe. (Komonjinda, 2011) Recent studies (Saelee et al., in prep) indicate that the alignment of this temple reveals the relation with the observation of Spica and could be used for the intercalary-month year in the luni-solar calendar that was used in the area.

Naked-eye Observation at Historical Sites

In order to analyse the usage of astronomical sites, researchers have to collect naked-eye observation data from the site as it was done by ancient people. Although the observation can be simulated from modern technique, to understand what people did and gain the same environment, one has to be in the same situation. Researchers also have to be patient as some phenomena could be observed once a year.

To conduct this observation, it is required special access to the national reserve area both during the tourist visiting time and after dark and a long term observation. This activity interests people by many means. Archaeologists and historians can gain the experiences on how ancient people used the sites. This could help them understand more about the site such as the interpretation of inscription. The observation also supports tourism. The knowledge of astronomy can make the story of the site more interesting and the observation experience can gain tourists an invaluable experience.

The most important thing is the impact on local people. Many historical sites were abandoned as it was useless by means of present day activity. The knowledge of astronomical use of sites should be spread out, not only to keep the site persistent but also to take pride in local knowledge.

In 2020, the National Astronomical Research Institute of Thailand plans to have a training program on Archaeoastronomy including the Naked-eye observation. But due to the COVID-19 pandemic, the training was postponed to 2021.

For more than thirty years, the integrated learning to the unified concept technique was initiated and used at Chiang Mai University to train undergraduate Science students and later apply for high school students in science classroom in university program (Wongta et al., 2019) The program found a success story as it gives the new generation scientist understand the relation between science and history.

The Citizen Night-sky from Valparaíso

Speaker: Sebastián Ramírez Alegría, CITEVA, Universidad de Antofagasta, Chile

During the summer of 2016, in a small bar in Valparaíso (Chile), there was talk series dedicated to the night-sky observation. The activities were open to anyone interested and focused on recognizing several objects in the sky using only our eyes. The participants started recognizing their knowledge, realize the challenges (both temporal and spatial) associated with observing the sky in the city, and finished observing different celestial objects in the summer night. In this talk, I will present this brief project, its activities, problems, and main learnings -for participants, myself, and future projects.

Talk link: `https://youtu.be/0iCHdU1aM6k`

Disclaimer: This text is a composition of opinions based on my experience in Chile as a professional astrophysicist doing outreach. Please consider I am not an expert on outreach activity design.

For most of us, the first experience of the sky at night is using only our eyes. But with time, we are exposed to high-resolution and astonishing images of cosmic objects: planets and their satellites, nebulae with a variety of colorful shapes and shades, multitude of stars crowding the central region of star clusters, or galaxies grouping and deforming themselves into galaxy clusters.

These beautiful images require special equipment, previous technical knowledge, and time for acquisition, reduction, and construction. The general public does not consider the last two groups of needs (knowledge and time) as a mandatory requirement and usually gets captivated by the idea: "to observe the sky, I need a (powerful) telescope." Many of the questions received at the end of outreach activities in Chile reflect this general idea: "what telescope should I buy?" or "where can I buy a not-so-expensive but very-powerful telescope?".

A telescope is an instrument to amplify the spatial resolution for a reduced field of view. When we attach a camera, it also allows us to record the image and store the observed photons during a specific time (the "exposure time"). This characteristic makes it possible to record -and observe- dim objects and fine details in the sky. The telescope also has some disadvantages: it requires some basic knowledge of optics, is expensive and fragile, demands technical knowledge for its proper calibration and operation, and may need updates -with an associated cost- to improve our cosmic exploratory experience. And for many users, the smaller field of view and the monochromatic images are reasons for feeling disappointment.

No matter how large the telescope, stars are so distant they will always appear as dots. In the case of planets, colors look pale compared with high-res images. A combination of both phenomena affects nebulae and galaxies: distances pale objects hard to resolve[2]. For these reasons, buying a telescope may not be the best advice for a new explorer of the skies, particularly in a city[3].

On the other hand, the naked-eye sky is a low-cost natural activity, accessible for most inhabitants of a city. But this simple idea is not common to recognize. Trying to introduce the different observable objects using only our eyes in the night sky, I participated in a short workshop called "Cielo a Ojo Desnudo." This workshop invited anyone around the "Trabalengua" cafe in Valparaiso to two activities:

1. A regular talk by an astronomer (myself) about the objects observed in the night sky: this talk was relaxed, inviting to share experiences and trying to remember what every participant had seen during the night. The Moon and stars were the most mentioned objects. With the help of panoramic photographs (Figure 1), we recognized planets ("these tingling dots in the sky, following the solar and lunar path"), star clusters (such as Pleiades and Hyades), and galaxies (the Large and Small Magellanic Clouds, plus our own Milky Way) as part of the "daily" night experience. After mentioning a variety of objects (human-made objects, planets, stars, the Moon, galaxies, clusters), I commented on the physics associated with them, and some examples of the ideas are:
   - Gravity puts together stars in "stellar clusters" or "galaxies." "Constellations" are a group of stars projected by chance in the sky close to each other.
   - The stars twinkle due to the atmospheric turbulence plus their tiny apparent size. They are very distant and hot objects, with different colors from red (cool stars) to blue (hot stars) and beyond (millimeter/submillimeter, infrared, ultraviolet, X- and Gamma-rays).
   - Planets do not twinkle despite the atmospheric turbulence. These objects look slightly bigger than stars and reflect the sunlight.

2. A night-sky observation in the city. After a short walk (less than 5 minutes), we reach an open place in the Playa Ancha's hill and start recognizing objects in the sky. With a finding chart printed before the activity, we see the difference of brightness and source distribution in the sky (understanding part of the Milky Way's structure), how the Moon

[2]To separate individual objects in the image. For distant objects, their details merge, forming a single source.
[3]Highly light-polluted cities forbid their inhabitants from this experience. Better illumination may recover this natural resource.

Figure 1: The night sky at Cerro Paranal, during the lunar eclipse of 21 December 2010. This panoramic photo shows the Milky Way, Venus, Saturn, the Zodiacal light, the Magellanic Clouds, and some easy to recognize constellations in the Southern sky. Credit: ESO/Y. Beletsky (CC BY 4.0).

> and planets move through a narrow path (the ecliptic), and the astronomical origin of the cardinal points. We realized the limited use of the finding chart for a specific night and hour, because of the changes in the sky, due to the Earth rotation and translation movements.

Because the activity occurs in the city, all participants experience the effects of night pollution when they try to observe stars at different parts of the sky (closer to the hills v/s closer to the zenith). Because it happens in their neighborhood, the cost is low and connects with their night sky (it is part of the city and the neighborhood).

This activity happened only in February 2016, but the general talks continued for two more years. The participation in the 2016 series was good; most of the participants attended all the workshops/talks: astronomy, knitting, bread-making, and mathematics. The general cross-disciplinary interest reflects the spirit of Valparaíso's inhabitants and the city itself: one of the main ports in the Pacific at the beginning of the XX century, host of many Chilean cultural explorations: film recording, football club, newspaper, astronomical observation with telescopes, firehouse, and a long etcetera, happened first in Valparaíso.

Star Stories at Kottamia Observatory

Speaker: Ola Ali, National Research Institute of Astronomy & Geophysics, Egypt

Every year, hundreds of astronomy lovers visit Kottamia Observatory to enjoy the clear sky and learn about astronomy. Whether they are school students or adults, the observatory staff always creates a program that suits each group. Mostly, I prefer to work with kids 6-15 years old. At this age, kids are fascinated by the sky and are passionate to learn all about it. When designing a program about astronomy and night sky, I like to integrate stories from ancient astronomy mythology. This provides a fun learning experience and keeps the attention of my audience. Over the years, the outcome of these visits has been amazing. Some of my students choose astronomy as graduation projects. Others even chose to pursue astronomy academically.

Talk link: https://youtu.be/_jjBjxbebqQ

National Research Institute of Astronomy and Geophysics (NRIAG) is a Research Institute that follows the Ministry of Higher Education & Scientific Research here in Egypt. It has 2 main Divisions: Astronomy & Geophysics, It has 5 departments, 12 laboratories, around 300 staff members, and tens of facilities all over Egypt. NRIAG has a very long history of astronomical and Geophysical observations since it was established in the year 1839 as a Royal observatory at Bollak then moved to ABBASIA in the year 1868 before it was moved to the current location at Helwan in 1903; making it the oldest research institute in North Africa and becoming one of the world heritage sites in Science and technology.

Besides its role in scientific research, NRIAG has a great role in community services and the dissemination of scientific culture; especially in the field of Astronomy. One of these services is publishing simplified scientific information throughout different social media platforms, such as Facebook, Twitter, and Instagram, also, NRIAG has a channel on YouTube containing lectures to amateurs and professional astronomers and geophysicists. IAU National Outreach Coordinator for Egypt, Prof. Somaya Saad is from NRIAG, also NRIAG hosts the activities of the Scientific Society of Astronomy & Space in Egypt, the society aims in the first place to carry out outreach events.

One of the special facilities of NRIAG is Kottamia Astronomical Observatory. It is located approximately 80 km away from the center of the capital "Cairo" in the direction of the Suez city, over a mountain that rises 450 meters above sea level. The Observatory was established in 1964, as an extension of Helwan observatory. It contains a 74-inch telescope, it is the largest telescope in the Arab world, the Middle East, and North Africa. A large number of scientists and researchers in the field of astronomy and physics use this telescope. It is unique in terms of its location, and its around 250 net clear nights throughout the year.

Kottamia Observatory is regarded as a small scientific city, besides the 74-inch telescope, there is a 14-inch Celestron Telescope, a number of rooms equipped for the convenience of Observers, a plant to generate electrical power (Diesel generators) to run this amount of equipment and huge electric motors for the Telescope. There are also two water reservoirs, a Garage, Kitchen, Engineering laboratories, and workshops for electricity and mechanics, a lecture hall, and a number of small telescopes used for the observatory visitors.

Every year, hundreds of astronomy lovers visit Kottamia Observatory to enjoy the clear sky and learn about astronomy. Whether they are school students or adults, the observatory staff always creates a program that suits each group. For me, I prefer to work with kids around 6 to 15 years old. At this age, kids are fascinated by the night sky and are passionate to learn more about it.

I start the visit before sunset with a tour at the observatory and the 74-inch telescope, then I took them to the Lecture hall to give them a small talk about some fundamental definitions of astronomy especially the night sky such as (celestial sphere, stars, planets, constellations, conjunction, and so on). Also, I show them that they can practice stargazing from their home, not only from the observatory, they can observe the sky from everywhere, the limit for what they can see is the pollution and lights. I show them a photo of any conjunction I took from my balcony, and motivate kids to observe these phenomena as they are the most visible events in the city's sky. I tell them the date of the next conjunction and ask them to tell their teachers or parents to help them see it. After that, I start talking about the constellations, the most exciting part for me and the most memorable part for the kids, I explain the idea of constellation & whether this image is real or not, then I show them pictures containing some stars and ask them to use their imagination to connect the stars and create a figure. At night we set our telescopes and start to observe the sky. I guide them through the different constellations, to make it easier for them to remember, I tell them the myth around each constellation, for example, the Greek mythology of Cassiopeia (the queen), Cepheus (the king), Andromeda (their daughter), Cetus (the sea monster), Perseus (who saved Andromeda). These star stories inspire kids to observe the sky and create their own stories. We spend the rest of the night laying on our backs and looking at the sky.

Over the years, the outcome of these visits has been amazing. Some of these kids choose astronomy as a graduation or science project in their school. They ask their teachers or their parents to communicate with me and inform me that they have succeeded in their project because they choose astronomy, and their teachers and colleague were fascinated by the projects, also I noticed that the thing the kids remember the most, is the stories about the sky and that they continue to observe the sky from their houses. Others even chose to pursue astronomy academically, one of these kids chose to enter the faculty of science just to study astronomy. I met her in her first year of college and she was very proud to achieve her dream, the dream that started when she visited NRIAG and saw a telescope for the first time in her life and her interests grew after she saw the wonderful night sky of Kottamia observatory.

Star Tales that Tell the Origins of their Names

Presenter: Hani Dalee, Arab Union for Astronomy & Space Sciences, Olympiad Coordinator & IAU/NOC Qatar, Qatar

Most of bright stars are well known to astronomers and amateur astronomer, but that is because they read their names in the books or to heard about them. In our talk, we will give some examples about some of these names and where they were derived from.

Poster link: https://astro4edu.org/siw/p59

If you try to look carefully into sky charts, paper or digital-based ones, you will be astonished to discover that most of these stars have Arabic origins that occurred during the Arabic-Islamic civilization, along with translations carried out later in Europe. Naming procedure has been done for the last 1000 years. Origins of these names go back to the following points: Lunar Mansions, Stars with Double Names, Arabic Constellations and Stars of Translation & Transliteration.

Al-Sufi & His Book: It was Abdul-Rahman Al-Sufi (903-986) who put the most important astronomical book in the Arab-Islamic civilization "The Book of Fixed Stars", in which he re-studied Ptolemy's Almagest and drew a figure for each constellation. He re-calculated and described the position of each star on the figure and put them in a list. Finally, he mentioned the tales of stars in the Arabian sky from where stars in modern atlases are being named until now. Arabic origins of star naming can be summarized as follows:

1. The **Lunar Mansions** are stars one or more where the moon is seen to reside every night. There are 28 mansions according to the length of the sidereal month. Of these mansions Aldebaran in Taurus, Sheratan & Botien in Aries, Al-Heka in Orion, etc.

2. Constellations in the Arabian Sky: Arabs used the stars according to their need to travel in the desert during different semesters of the year. Along with that, they wrote their own star legends, some talking about the love story between Suhail (Canopus) and Thurayya (Pleiades), another talks about Vega the eagle who tries to hunt the baby camel at the same time with the two wolves, a third is telling the tragedy of the poor's food plate, another nice one is talking about BenatNash (daughters of Nash) who are still chasing

Al-Joday (Polaris) for killing their father, and many other beautiful tales which actually write down their heroes names above in the sky, those stars we are still telling their names until now and thereafter.

3. The Arabian sky was recognized by "Names of stars in pairs". These pairs are divided into three categories:
   Star Pairs with a Single Name: They are two stars close to each other, they are given the same name with a little difference such as saying northern & southern, or brighter & fainter, etc. For example, Farkadan (Two Brightest), Diban (Two Wolves), Nasran (Two Eagles).
   Groups of Stars in Pairs: They are stars making pairs of shapes with the same name. For example, Nasakan (Two Lines), Kaffan (Two Palms), Thera'an (Two Arms).
   Individual Stars in Pairs: They are two stars, together, they are given a single name. For example, Thira' (The Arm), Niyat (The Arteries), Shaula (The Sting).

4. The Role of Translation & Transliteration in Star Naming: Arabs knew scattered stars here and there and some shapes according to their needs. They did not divide the sky like what Ptolemy had done in Almagest, therefore, when AbdulRahman Al-sufi wrote his book "Sowar Al Kawakib", he adopted Ptolemy's work. Actually, Al-sufi has done a great job when he re-drew constellation figures and described their individual stars in a list, and because the book was in Arabic, new names such as Deneb, Alpheratz, Thuban, Kaus, Rasalgethi and many other names appeared when translations and transliteration of the figures from Al-sufi's and other astronomical books took place in Europe. These new Arabic names were not known to Arabs themselves in their desert.

The total ratio of Arabic star names in the sky chart is about two thirds of the total number of names. Even if we only count the 2017 IAU Catalogue of Star Names (IAU-CSN), which is made of 240 Stars in total, 163 Arabic Stars = 67%. Because new software and mobile applications appear, more and more new names are still appearing, most of them are Arabic in origin.

Astro-cultural Tourism in Romania - Another Way of Doing Astronomy Education

Presenter: Elisabeta Ana Naghi, Education Ministry, Romania

Victor Anestin – considered to be the father of Romanian amateur astronomy: "Numbers and long equations are not the bait with which the admirers of heaven can be caught". In the last few years, we have witnessed a series of private inquiries unveiling a special kind of astronomical heritage in Romania. We group the main objects of interest for the Romanian astro-cultural tourist into the following list: 1) Astronomical ornaments to be found on old village houses, 2) Astronomical timekeeping devices, sundials, 3) Cosmological representations inside churches. The list may go on but what is most important is the fact that astro-cultural tourism can be a good starting point for astronomical education in the case of youngsters, adults and the elderly alike.

Poster link: https://astro4edu.org/siw/p60

Victor Anestin (1875-1918) – considered to be the father of Romanian amateur astronomy – once said: "Numbers and long equations are not the bait with which the admirers of heaven can be caught". In the last few years, we have witnessed a series of private inquiries unveiling a special kind of astronomical heritage in Romania. Soon this legacy may constitute the core of a special kind of tourism involving astro-cultural travels. As a dark night forms the underlying resource for celestial tourism (visiting unpolluted skies for observational or photographic astronomy), we group the main objects of interest for the Romanian astro-cultural tourist as follows:

1) Astronomical ornaments to be found on old village houses. Stylized astronomical decorations pertaining to certain celestial events such as eclipses, comets or other solar imagery have been discovered mostly in northeastern and northwestern Romania.
2) Astronomical timekeeping devices. The tourist can visit about 200 Romanian sundials, most of which are concentrated in the historical province of Transylvania: attempts to coalesce them into specific sundial trails have been made for the cities of Alba Iulia (2015) and Cluj-Napoca (2021); in the first case a flyer has been published, in the second case even a booklet.
3) Cosmological and astrological representations inside churches. A few frescoes depicting historical solar system diagrams (some geocentric, some heliocentric) can be found inside some of the picturesque, small wooden churches scattered in the area around Zalău and Baia Mare: they constitute a great starting point to the history of astronomy for the casual visitor. Finally, some churches also exhibit frescoes of the zodiac signs, though the link of religion and astrology is a complicated, albeit an interesting one. It is rather remarkable that the vast majority of these discoveries and the efforts to make them known have been undertaken by amateurs. The list may go on but what is most important is the fact that astro-cultural tourism can be a good starting point for astronomical education in the case of youngsters, adults and the elderly alike.

Discussion summary

All speakers and participants agreed that regular observations are a key ingredient in lesson plans to achieve this. These can be as simple as drawings of the phase of the moon, but there is no limit in how elaborate students can be to combine night sky observations with creative interests as well. And we concluded that for a true learning experience, students need to learn about the motion of stars with the use of a planisphere and other non-digital tools rather than a phone app that might distract them from the sky as well. Students translate what they learn into mental models and it is important to ensure that those mental models are correct as it will be difficult to change them further on.

If night sky observations with teachers and students are possible, fast moving objects such as the International Space Station can be used as natural laser pointers. Historical astronomical sites are of high interest to not only astronomers and while very fascinating in itself, can help us to interest a broader population in astronomy as well. It was pointed out that even in very light-polluted areas, the moon can be observed. Depending on the region of the world, background knowledge in the population can vary related to reasons not rooted in the school system as well, for example, if many observatories are close by or if the path of the Sun is observed for religious or cultural reasons.

Look up, learn and enjoy!

Online Formats for Astronomy Education

Session organiser: Samir Dhurde,
Inter-University Centre for Astronomy and
Astrophysics, India

Session overview

The internet and its associated technologies have together provided a wealth of opportunities, expanding the reach and approaches of not only science but more importantly science education. In the context of astronomy education this has led to a great increase in the number of resources available online. It can be challenging for novice educators (even experts) and students to filter through these and select the better ones. This session brought together a range of talks and posters, which provided a small snapshot of not only what is available in the context of online resource repositories and formats, but also some of the best practices and solutions related to taking astronomy education online. Some of the resources include e-books, e-course websites, citizen science projects, lab activities, sky viewing tools, and various repositories. The session aimed to show the ease and also the hurdles faced by those who have actually tried their hand at this. It is hoped that it will give the audience enough information and confidence to use an online resource for teaching or starting their own platform. The session mentioned mostly open-source and free content that can address a key barrier related to equity and accessibility. These have to be considered when developing online resources for astronomy education.

Online Resources for Teaching Astronomy

Speaker: Chris Impey, University of Arizona, USA

The growth of the Internet has facilitated the easy availability of resources for teaching astronomy, particularly at the introductory level. This overview concentrates on resources that are free or open access. Basic materials like textbooks, lab activities, and large numbers of astronomical images can be found, along with higher-level items such as concept inventories and interactive instructional tools. Instructors can find teaching guides and tips for interdisciplinary approaches to astronomy. There is also a small but growing research literature on astronomy instruction to be found online. Taken together these resources are of great value to both novice and seasoned instructors.

Talk link: https://youtu.be/tB3-KvJE01I

This brief summary of (mostly free) online resources accompanies an oral presentation for the Online Platform theme at the 3rd Shaw-IAU Workshop on Astronomy for Education.

The Internet has transformed the teaching of astronomy. Before 1995, instructors were mostly reliant on a printed textbook, 35-mm slides, and their own lecture notes. Depending on local resources, they might also be able to incorporate labs, hands-on activities, and the use of small telescopes. Now, they can choose from a wide, and occasionally bewildering, array of online resources to augment what they do in the classroom. The challenge is to find the tools that are either evaluated in peer-reviewed publications or have proven their efficacy in other ways.

Textbooks: A free, open-source textbook introductory astronomy is Astronomy by Andrew Fraknoi, David Morrison, Sidney Wolff, et al., published by Open Stax (http://openstax.org/details/astronomy). Another comprehensive online book, consisting of 520 articles, organized into 19 chapters, is Teach Astronomy by Chris Impey, et al. (www.teachastronomy.com).

Laboratory Activities: A listing of both full collections of lab activities (from university astronomy departments) and a set of individual activities is Compilation of Free Astronomy Lab Activities by Andrew Fraknoi (http://www.fraknoi.com/wp-content/uploads/2017/12/Laboratory-Activities-for-Astro-101.pdf).

Instructional Tools: ComPADRE is a digital library of educational resources in physics and astronomy intended for instructors and students, sponsored by the American Association of Physics Teachers and the American Astronomical Society (https://www.compadre.org/astronomy/). Merlot has college-level educational resources in a wide range of academic disciplines, with about 800 astronomy items (https://www.merlot.org). Hosted by NASA's JPL, the Center for Astronomy Education (CAE) features a large collection of resources that have been tested and validated by fifteen years of research on pedagogy and student learning (https://astronomy101.jpl.nasa.gov/).

Concept Inventories: A concept inventory is a research-based assessment that probes a student's understanding of key concepts in a subject. Typically, it is administered with a carefully defined curriculum, and learning is measured before and after the concept has been covered in class. Key astronomy concept inventories are at https://www.physport.org/assessments/. One early inventory, the Astronomy Diagnostic Test (ADT), can be found at: http://solar.physics.montana.edu/aae/adt/.

Short Videos: Videos can provide useful augmentation or enrichment for an astronomy class. Astronomy has long been well served by long format (video from national media producers such as PBS/NOVA and National Geographic. But a relatively new phenomenon is short format video, often made by individual scientists, NASA or ESA missions, or educators, often with inexpensive equipment. YouTube is the place to find many excellent videos on astronomy; a web search for astronomy returns 2.9 million results, with about 5000 new videos added every day. A few noteworthy resources in this arena include: the Astronomy Crash Course series, hosted by Phil Plait and distributed by PBS Digital Studios (https://www.pbs.org/show/crash-course-astronomy/), the 110 videos made by the AGV team (https://www.youtube.com/ActiveGalacticVideos/), short videos to go with sections of an introductory astronomy course, curated by Andrew Fraknoi (https://www.oercommons.org/authoring/18222-short-videos-for-use-with-each-chapter-of-openstax), collected from space agencies, public TV, observatories, and science museums.

Interactive Tools: Kevin Lee at the University of Nebraska has created a set of interactive materials on astronomy for use at the introductory college level or the high school level. The materials include dynamic think-pair-share questions with 500 items in 22 topic modules (http://astro.unl.edu/classaction/) and 15 online lab modules built around simulations of physics and astronomy phenomena, with students able to set up initial conditions and vary parameters (http://astro.unl.edu/naap/).

Sky-Viewing Tools: The number of programs and apps to help students learn the sky has grown astronomically in recent years, with new and powerful versions coming out regularly. The exemplar of integrating images from ground- and space-based telescope with a view of the night sky is the WorldWide Telescope (WWT), an open-source collection of applications and data, hosted on GitHub, with the data available in the cloud (http://www.worldwidetelescope.org/webclient/). The project provides over 50 examples of "tours" that instructors can use in the classroom to give students a sense of the richness of the night sky. As an extension of its detailed maps of the Earth, Google makes available sky maps (https://www.google.com/sky/), and zoomable maps of the Moon and Mars, including 3D models and 360-degree views. The best open-source planetarium software is Stellarium (http://stellarium.org/), which is supported on all major operating systems.

Citizen Science: Citizen science has millions of volunteers working on thousands of projects across all fields of science, without formal training. For a database of projects, see https://scistarter.com/. The archetypal citizen science project in astronomy is Galaxy Zoo (https://data.galaxyzoo.org/), where non-scientists classified 900,000 galaxies with a reliability similar to that of professionals. Galaxy Zoo expanded a few years ago into Zooniverse (https://www.zooniverse.org/). The site has a million registered volunteers. Astronomical projects include looking for solar coronal mass ejections (Solar Stormwatch), detecting ISM bubbles (Milky Way Project), detecting extrasolar planets (Planet Hunters), analyzing Mars images (Planet Four), looking for stars where planets are forming (Disk Detective), and finding previously undiscovered asteroids (Asteroid Hunter).

Image Collections: The iconic site Astronomy Picture of the Day (APOD) started at the same time as the Internet, in 1995 (https://apod.nasa.gov/apod/astropix.html). Its first post had 14 views, and by 2012 it had reached one billion views. With over 8000 images plus explanatory captions, it is one of largest repositories of astronomical imagery on the Internet. Hosted by the Infrared Processing and Analysis Center (IPAC) and sponsored by NASA, Astropix is an archive of over 7000 images from the world's major observatories (https://www.ipac.caltech.edu/outreach/project/astropix). The largest source of images outside the United States is the archive of the European Southern Observatory (ESO). There are over 12,000 images on their site, plus over 3300 short videos and animations, all free to use for educational purposes (https://www.eso.org/gallery/).

Platforms to Create your Own Online Astronomy Courses

Speaker: Amit Dhakulkar, North-West University, Mahikeng, South Africa

Several online platforms are available for teachers to use, create and host their own Open Educational Resource (OER) courses. But how does one choose which platform to use? To answer this we review some of the common free and open-source platforms that can be used to develop and deliver courses using a rubric developed for this purpose. We discuss the features of the platforms for pedagogical features with a special focus on the requirements of astronomy education. We also discuss technical and infrastructural requirements of the platforms. We will also look at features of the platforms which offer free hosting services for online OER courses. Finally, some aspects of open licensing and its implications specifically for the educational context will also be elaborated.

Talk link: https://youtu.be/G40sWGfqXaE

Online learning has become very significant in the past decade due to increase in computing devices, connectivity and Open Licensing framework. With Covid-19 pandemic, online learning has assumed special significance. Various institutions and individuals offer online courses in the form of Massive Open Online Courses (MOOCs). Creating and deploying courses has become increasingly simple for authors with the rise of several online platforms which allow MOOCs. Several platforms exist offering multiple ways to create and deploy online courses. We discuss some major platforms, their features in the context of Astronomy Education.

Several online platforms are available for teachers to use, create and host their own Open Educational Resource (OER) courses. But how does one choose which platform to use? To answer this, we review some of the common free and open-source platforms that can be used to develop and deliver courses using a rubric developed for this purpose.

We looked at three major free platforms - **Moodle** (GPL V3; `https://sandbox.moodledemo.net/`), **P2PU** (MIT; `https://course-in-a-box.p2pu.org/`) and **OpenEdx** (AGPL & Apache; `https://studio.edx.org/`) - for developing and deploying online courses with the following criteria: Free and Open-Source licensing (not proprietary), Wide usage and Customisable, Self-Management, and Available Support.

The talk presents the basic anatomy of an online course with detailed sharing based on platform features like Learner Interface, Authoring area, Assessments and Analytics that are useful to know for anyone planning to host a reasonably large online course.

Most important for the educators in this session, there is a discussion on the features available for authors and also tips about how to decide on content. In brief, it always helps to have a basic outline which can be modified as required. These platforms may help you better if you have your Learning Objectives clear and also a Course Outline. Some amazing assessment types are available now, which can make the author's life easier and even improve the students' experience.

The above three platforms are also reviewed based on these, as well as their Technical and Infrastructural requirements. These platforms allow you to host the course (or multiple courses) off your own server and so these are important to consider. Of course they also offer free or paid hosting services for online OER courses so that you do not have to worry about the maintenance.

Finally, some aspects of open licensing and its implications specifically for the educational context are also elaborated. Open Educational Resources refer to content which is licensed in a manner which allows for (re)use, remix, adaptation, and distribution with certain conditions. Releasing content with an open license allows for more access and the content can be reused to build other resources. Several astronomical image and data repositories are available as OERs. IAU's astroEDU also has peer-reviewed science education activities. These and many more relevant OERs exist which can help create your course by using, adapting, remixing them. Thus to end, we stress that licensing is important: Please make and release your course as an OER so that everyone benefits!

Create Better Interactive Apps

Speaker: Edward Gomez, Las Cumbres Observatory, California and Cardiff University, UK

Interactive websites and apps are a highly scalable way to share a research topic or educational concept. Before starting on a new project of this sort, you should consider 4 basic principles to ensure your app has the maximum impact. During this talk I will discuss the meaning and importance of these 4 principles. They are "Goals first", "Who is your audience?", "Time is precious" and "Thinking Technology". Finally I will give 2 case study examples of how I used these in projects I have worked on, namely "astroEDU: a peer review platform for astronomy education" and "Star in a Box: an interactive app to explore the lifecycle of stars".

Talk link: https://youtu.be/IyCP-S3_lr0

Starting a new project always holds a lot of excitement, particularly if it is to create an interactive website or app. Be careful not to confuse your excitement for the project with how others will perceive it. I have developed many interactive websites in my career, some have been successful and others, less so. The projects which have both been popular and endured have been ones in which I did not let my, or my team's, excitement run away with the development. We want to maintain enthusiasm for the project but we also do not want to get lost in the details. I use four basic principles for planning projects, see Figure 1.

Goals First: Before you start coding, graphic design work, or content creation, sit down with your team and discuss your goals. What do you want to achieve with this app? Make them concise and few in number. For a small project 1-2 goals are good. For a larger project, setting 3-5 goals is appropriate. Make them general, not too specific. You want the majority of people who engage with your app to achieve their goals.

Who is your audience?: Understanding who your audience is, is crucial to the success of your project. Trying to make your app appeal to everyone is not a good idea, particularly for an educational project. You should at least have a primary audience, e.g., high-school students. It is acceptable to have multiple groups, because there are synergies between different audiences in education, e.g., high-school students and teachers. Refer to your goals to make sure the audience you identify can achieve your goals.

Time is precious: Even if you have done an excellent job of making your app entertaining, there will be an initial threshold the audience needs to get through to get to the interactive part. Make sure that the background information or set up is concise and easy to follow. If your app requires your audience to do a lot of reading, this will turn away some of your audience. If your app is tedious, this will also limit the number of people who complete it, and who achieve your goals. This step is very important to consider in your design and development phase.

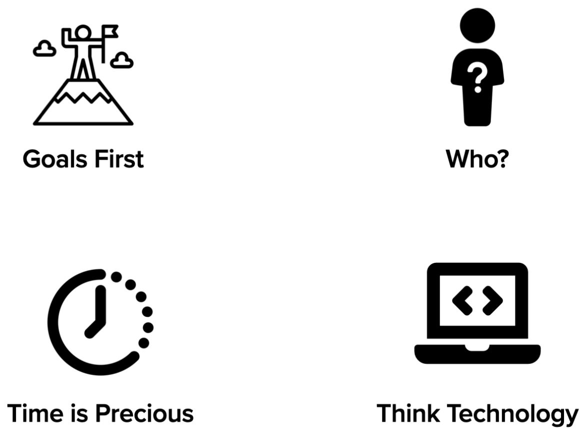


Figure 1: The four basic principles of better app design.

Think Technology: There are many different considerations to consider when developing your project. The audience you have identified may have technological limitations. For example, if your audience is schools in the developing world, you should make sure your website can be viewed using mobile internet and on mobile devices. Your project may also have a life longer than the anticipated lifetime. Plan for who will maintain your app, otherwise technology advances may make your app defunct (e.g., Flash websites are not compatible with modern web browsers). If you are invested in your project, you will become the de facto maintainer.

There are potentially many other stages that you will need to consider to make your app a success, including taking input from your supporting institution or funders. Remember that just because you find your app entertaining and inspirational does not necessarily mean anyone else will. These four basic principles give you a good starting place when developing website content, interactive websites, virtual or augmented reality apps.

A Free Online, Open-source, Introductory Astronomy Textbook

Presenter: Andrew Fraknoi, Fromm Institute, University of San Francisco, USA

The non-profit OpenStax project at Rice U. publishes free, on-line, open-source, textbooks in every introductory field in college/university. The astronomy textbook in their series, by senior authors Andrew Fraknoi, David Morrison, and Sidney Wolff, now has over 1,100 faculty adopters, and has been used by half a million students worldwide. So far it has saved North American students more than 40 million dollars in astronomy textbook costs. The book's development was aided by almost 70 astronomers, who helped with making sure the science was accurate and pedagogy effective. The book is easily updated and has links to a wide variety of web pages and apps. The book's Open Education Resources Hub has over 35 free ancillary materials. See: http://openstax.org/details/astronomy.

Poster link: https://youtu.be/-Xo-SqVE0Gk

The non-profit OpenStax project at Rice University, supported by a group of major US charitable foundations, is working to produce a free, professionally-edited, open-source, on-line textbook in every field in which college students take introductory courses. Currently, they have over 40 such books published.

My coauthors, David Morrison and Sidney Wolff, and I had been writing textbooks for commercial publishers for a while. The publisher of our last book became such a large conglomerate, that they found themselves publishing six competing lines of astronomy textbooks simultaneously! Ours was neglected and left to wither as a result. So, we were delighted to be approached by OpenStax to spearhead the project to write their free introductory astronomy textbook.

The book, cleverly entitled "Astronomy," was published in 2017, and despite the fact that our publisher has no money for publicity or sales reps, it has been found by astronomy instructors looking for ways to reduce the cost of their courses. Today, the book is being used at over 1100 institutions, and has had over half a million student readers. The publisher calculates that this has saved US students more than $40 million in astronomy textbook costs so far. Anyone can read or download the book at: http://openstax.org/details/astronomy.

In producing the book, we had help from over 60 colleagues in astronomy and astronomy education – both with making sure the science was up to date and with assuring effective pedagogy. Among these colleagues are: Debra Fischer (Yale), Heidi Hammel (JWST), Steve Kawaler (Iowa State), Lloyd Knox (U of California Davis), and Martin Elvis (CfA). Available for

Textbook senior authors: Sidney Wolff (NOAO), David Morrison (NASA Ames), and Andrew Fraknoi (Foothill College), seen a few years ago.

on-line reading, and downloadable for all devices (including an OpenStax phone app), the book is being updated regularly. The nice thing is updates only require moving electrons around, and not chopping down trees.

Among the features of the book that colleagues have told us they find useful are:
1) mathematical formulas and worked-out examples are in boxes, so they can be included or skipped as the instructor wishes;
2) each chapter includes a summary, plus review questions, thought-provoking questions, numerical problems, and collaborative group activities;
3) recent web resources (including videos, animations, and apps) are provided as live links throughout the book and more are given at the end of the chapter;
4) profiles of astronomers (past and present) are included in the chapters as boxes;
5) short sections point out connections between astronomy and other fields students know.

A key aim of the book is to present astronomy in ways that are accessible to non-science majors, who make up the vast majority of the students who take intro astronomy in North America. The chapters are filled with analogies taken from the student's own lives; with clear discussions of HOW we know things, not just WHAT we know; and with occasional touches of humor.

The book has an Open Education hub of free shared resources at: https://www.oercommons.org/groups/openstax-astronomy/1283/?__hub_id=27. Adopters can use the hub to get ancillary materials developed by the authors or by fellow instructors, such as: a list of free short videos on the web to go with each chapter of the text, a guide to free lab manuals on the web for introductory astronomy courses, a list of science fiction stories with good astronomy, organized by topic, a guide to including more multi-cultural astronomy in your course, a primer on things a first-time Astro 101 instructor needs to know and do, a resource with many links to the contributions of women to astronomy, a guide to how instructors can respond to pseudo-scientific claims brought up by students (such as moon-landing denial, creationism, astrology, UFOs, etc.), a summary guide to using the free planetarium software called Stellarium, PowerPoint slides with all the book figures, etc.

A new Learning Management System, keyed to the free textbook, has recently been developed by one of OpenStax's partner companies. The system, called Expert TA Astronomy, includes: more than 1100 multiple choice questions, more than 1100 true-false review questions, 276 calculation questions (with different values for different students), 234 graphical questions (including ranking, sorting, labeling, and chapter review.

All of these are automatically graded by the system. In addition, the roughly 800 essay questions from the book are now also included. You have to grade answers to these yourself, but then the grade is added to the gradebook being kept by the system. Expert TA: Astronomy has other security and convenience features that make homework, tests, and grading easier to manage. See: http://theexpertta.com/astronomy.

We encourage you to take a look at the textbook when you have a chance. While it is only available in English at present, we hope one day to see it translated into other languages and used in other parts of the world. If you have any thoughts about the book and how else it can be useful, please feel free to contact the author.

Astronomical Midlands: Engaging Rural and Online Communities in Ireland with Radio Astronomy

(What we have learned from running a variety of online events - Top Tips!)

Presenter: Áine Flood, Trinity College Dublin, UK

We will discuss tried and tested methods for communicating astronomy concepts in an online format. We have used and will examine the pros and cons of various ways to interact with and engage participants and audiences through live video calls. This includes stepping back from the screen for hands-on, tactile demonstrations and activities specifically developed or modified to work in a remote or at-home setting, keeping interest and attention with younger audiences by changing formats and allowing for multiple forms of interaction to suit various learner types, ages and ability levels.

Poster link: https://youtu.be/dlcft1fUNLQ

The AstroLands team at I-LOFAR ran online Astro Camps open to different age groups during school holidays, first in summer 2020, again at the spring/Easter break in 2021 and most recently this summer. The participants were divided by age, and the themes of astrophysics and space science were explored over the course of the camps, running daily from 10am to 1pm.

The sessions were varied to keep interest and focus. Key tips are to be organised, very organised! Test and check all parts of your event, test and become familiar with the platform you are using, have backup options for any technology features and options if participants have trouble with their internet connection, or other issues.

We had an online timetable to hand with links for all materials. Whatever you will need, have it all in one place, so it can easily be found if anything goes wrong or crashes! Also have a backup option for everything. We had all resources for the camps shared and accessible to all facilitators, so that the leading presenter for each section could change at the last minute if necessary.

Wherever possible, have a flexible timetable! "Live" does not always go according to plan, and when it is online there are extra challenges to changing plans on the spot. We did include guest speakers for these camps, but for the most part had them on in the first morning slot, so that if the questions ran on we could modify our own activities to the available time left. The facilitators also kept in touch to communicate any issues or delays using a separate chat platform such as Slack.

Know your capabilities and keep numbers restricted if necessary. For these camps, numbers were strictly limited to allow for an immersive and interactive experience. With three facilitators, we restricted the capacity to 21 participants per camp. This allowed for all to have a chance to ask questions of guest speakers and participate in group discussions, and three breakout rooms with small groups of seven participants, ideal for all to be fully involved in the activities. Do make use of helpful technology features, such as breakout rooms. This is especially helpful with a young audience to keep things moving and fresh.

It is important to keep the structure varied. For these camps we switched between listening and discussing to more involved hands-on activities. Typically, we would have a guest speaker come to chat to the group and answer any questions they had. We followed the talk with an activity, split into breakout rooms and got hands-on with a building, designing or creative task. The aim with this was to step back from the screen as much as possible for a more tactile experience. This was followed by a short break allowing for the breakout rooms to finish at slightly different times without impacting the next session.

With all guest speakers it is important to arrange a call prior to the event. This goes for all events, but was vital for the online Astro Camps. A short informal chat allowed us to get across the type of event we were creating, the tone and level it should be pitched at to create the right atmosphere, and also do practical checks such as screen sharing and presenter access on the video call platform. For these camps a casual, informal but of course well informed tone worked best.

It is important to remember there are benefits to running camps and workshops online. Although different to an in-person experience, it does allow people to join from wherever they are, and with younger participants we found that some with anxiety issues or different learning needs were more comfortable participating from the safety of their own home, and the option to interact and ask questions via the chat box instead of speaking up was appreciated.

Astronomy and Remote Learning: A Stellar Combination

Presenter: Christine Hirst Bernhardt, University of California, Santa Barbara, Endeavor STEM Teaching Project, USA

Next Generation Science Standards (NGSS) aims to bring Earth and space science to K-12 standards since now this comprises nearly 25% of all science content in US education system. This poster will spotlight several remote astronomy investigations, which are embedded into NGSS courses, while providing curricular justification. Spotlight lessons include: Satellites and Social Justice, Satellite Dynamics, Starlight, Solar Observations, Investigating Lunar Craters, and Citizen Science Aboard ISS. Participants will gain access to over a semesters' worth of take and go remote astronomy lessons for grades 7-12, in any NGSS course. Lessons can be taken as a sequence or a snapshot, and are ready to embed into a LMS.

Poster link: https://youtu.be/uvi1c42YlgA

Every child looks up at the moon in wonder and curiosity, yet for years astronomy education has had no place at the roundtable of K-12 standards. Fortunately for space enthusiasts, the advent of NGSS has changed that trajectory. Earth and space science have been elevated to National importance, and comprise nearly 25% of all science content in new standards. Despite this drastic shift, few teachers have the necessary background or resources to integrate these new topics. Further, many teachers are currently adapting their entire practice, including new topics, into remote environments. This setting is fortuitous for astronomy education; many resources can be easily integrated into remote settings, and even allow for greater investigation than in a face-to-face setting. Astronomy education has the capacity to empower students to investigate and design solutions to real world problems, while the space environment presents evidence for global patterns of change. This session will spotlight several remote astronomy investigations which are embedded into NGSS courses, while providing curricular justification. Spotlight lessons include: Satellites and Social Justice, Satellite Dynamics, Starlight, Solar Observations, Investigating Lunar Craters, and Citizen Science Aboard ISS. Participants will gain access to over a semesters' worth of take and go remote astronomy lessons for grades 7-12, in any NGSS course. Lessons can be taken as a sequence or a snapshot, and are ready to embed into LMS. Each lesson focuses on the value of studying space, and the implications for society. Lessons address equity in STEM, and are scaffolded to multiple modalities of learning, while utilizing real-time data (solar observations). Each lesson is free, and requires only internet access. Teaching remotely may present new challenges, however teaching space content should not be one of them. This workshop will provide resources for easy integration of topics, to maximize student engagement.

References: www.astrolessons.com, stellarium.org.

Teaching Online K-12 Astronomy in the USA

Presenter: Denise Wright, NASA Johnson Space Center Houston, NASA Playground, ISTE, USA

Schools across the United States have explored online learning options due to a shortage of K-12 teachers who specialize in physics/astronomy. In some schools astronomy is not offered because it is considered an elective course. Recently, a rise in online learning has occurred in the US due to the virus COVID 19. This has caused many students and teachers to pivot from face to face teaching to the online learning model. When designing and planning an online astronomy course, there are many considerations, for example, what type of learning management system will be used to deliver the course content? What units will be developed in an online high school astronomy course? This session will highlight the creation of a US high school level astronomy course using open education resources (OER) to educate students in an online learning model.

Poster link: https://youtu.be/ecTFFHg-jW4

In the United States, many K-12 schools are exploring the option of astronomy online education. Three reasons that astronomy is being offered through online learning are the shortage of earth science educators, the worldwide spread of COVID 19, and astronomy being considered an elective course, and thus, in some cases, not fitting into the public school schedule. Online learning has the opportunity to remove many of these barriers for students.

When designing an online astronomy course, a learning management system is required to develop the content. Moodle is the open-source learning management system that was chosen for this course. Moodle allows for a variety of online activities that may include forums, quizzes, tests, drag and drop items, and interactive assignments created and integrated by third party software such as H5P (https://h5p.org/). Moodle has many accessibility options for learners, such as screen reading, a consistent course layout, and multiple ways to provide written, audio, and video feedback on assignments.

Each unit for this online high-school astronomy course was created with a backwards design unit plan. This unit design pedagogy was originally published in the book "Understanding By Design" by Wiggins and McTighe. The overall goal of the backwards design unit plan is for educators to create each unit with the end goal and work backwards to design the learning experiences. In this high-school level astronomy course, the units that are included are: Unit One: Observing Our Night Sky, Unit Two: Nature and Light of Telescopes, Unit Three: Life and Death Of Stars, Unit 4: Incredibly Massive Objects and Gravity, Unit 5: Our Amazing Sun, Unit 6: Earth and Its Satellite , Unit 7: Planetary Motion and Gravitation, Unit 8: Our Solar System: Terrestrial and Jovian Planets, Unit 9: Comets, Nomads, and Exoplanets, Unit 10: Galaxies, and Unit 11: Cosmology.

The individual course lessons have been designed for students to learn about the foundations of astronomy. Some of the assignments include virtual labs, free mobile/ipad astronomy apps, open-source software, such as Stellarium, and close captioned videos from NASA. The students become citizen scientists by participating in several Zooniverse (https://www.zooniverse.org/) projects that are embedded in the course. Citizen science projects allow everyday people to help astronomers conduct simple scientific research. A few examples of citizen science projects that students participate in through the course are locating comets in a picture taken from a telescope, searching for exoplanets based on light curve data, and classifying galaxies based on their shape. Another exciting opportunity for students is that they have the ability to view the night sky with the South Carolina State Museum Observatory (http://scmuseum.org/explore/observatory/) distance-learning telescope. The telescope is a 1926 12 $\frac{3}{8}$ inch Alvan Clarke Refractor. It was retrofitted with a web camera and Sky Net, so that classrooms can go into live virtual meetings and have lessons on the moon, stars, and visible planets. The addition of the distance-learning telescope adds a higher level of engagement in the astronomy online course. The opportunity for high-school students to take an astronomy course online, provides an experience they may have not had and creates a modern understanding to this gateway science that inspires people of all ages and every culture.

Discussion summary

Some pertinent issues raised during the discussion included how to get new teachers and audiences into online learning, how to make content engaging and interactive, and how to provide feedback to students in relevant and familiar ways. A basic solution of a web-based free repository, along with live video calls, has been tried by some. More advanced solutions like hosting an online course may require some specialised help, for which teachers can refer to this session's content and also take help of any local tech experts or IAU OAE. Here it will be best to use open-source tools, which are also easy to get support for. The issue of engagement could be addressed by including exciting things like hands-on activities, astronomical images etc. Some teachers will find this shift daunting, due to lack of confidence, time or infrastructure. These could be reduced by tying up with local education/tech experts or through a community of practice. Resource producers could engage teachers at their local conferences, use live demos and support them to use online formats/resources for astronomy education. There are also the barriers of accessibility, including access to the internet itself. It was noted that there are examples of resources like an online course, running via a locally stored offline version. Other sessions in the workshop have also discussed accessible, low-cost and low-tech teaching ideas, which could be referred to in this case.

Remote Observing

Session organiser: Eduardo Penteado, Office of Astronomy for Education/Max Planck Institute for Astronomy, Germany

Session overview

Remote observing is a powerful tool to inspire and engage students in science, as it enables them to pursue scientific projects with real data. With the availability of remote telescopes sprayed over the world offering educational programs, the possibilities for teachers and students to take part in remote observing projects is a reality.

The aim of this session was to explore the key topics about remote observing applied to the scholar community. Contributions by a bunch of experts in the field were delivered in the format of talks and posters, sharing experiences and valuable information about how to engage with educational projects involving remote observing.

The first talk contribution was from Sascha Hohmann, who provided an overview of what is required for having an effective remote telescope education program. Michele Gerbaldi explained the importance of having a well structured management of a student project that includes remote telescopes observation. Alice Hopkinson explored ideas of using interactive challenges and character narrative to approach younger audiences, while Michael Fitzgerald described the reasons that might stop teachers using robotic telescopes in their teaching. Nayra Rodríguez Eugenio spoke about advantages and disadvantages of a variety of approaches, which can be used when working with robotic telescopes, and Mary Dussault spoke about how intentionally-designed remote observing experiences can produce positive learning outcomes. This session also included three interesting and important poster contributions. Priya Hasan highlighted some successful activities with students getting in contact for the first time with live astronomical data obtained with remote observing. Eamonn Ansbro told us how important it is for students to perceive their own projects, which is possible to be done with remote observing. Josina Nascimento shared details about a successful project of remote observing provided by amateur and professional astronomers, which mobilized hundreds of people in each event.

We hope that the information available in this session may instigate and be helpful for those who intend to take part in remote observing projects.

How to Set Up a Remote Telescope in Education

Speaker: Sascha Hohmann, Leibniz Institute for Science and Mathematics Education, Germany

With the spread of the Internet in remote locations, there is now the possibility of setting up high-quality telescopes in good locations that can be used for educational purposes. However, it is not enough to just set up the telescope in a good location and offer high-quality pictures. Equally important is the provision of a user-friendly interface and coordinated, tried-and-tested teaching materials like worksheets and additional information, since teachers often have neither the time nor the specific background knowledge to develop appropriate materials in everyday school life. This paper presents important aspects of setting up a remote telescope using the example of the Stellarium Gornergrat in Switzerland, including the possibilities of international collaboration.

Talk link: https://youtu.be/LjHoLRcy0-o

Remote Telescopes in Education: The level of light pollution is increasing worldwide, making astronomy in cities more and more difficult. Further observations in the field of astrophysics require additional expensive equipment, which is available at very few schools. Therefore, opportunities for students to record their own data in astronomy and astrophysics are often very limited. Even though there is a large amount of freely available data online, the entire acquisition process - including technical aspects - is part of understanding scientific process [1].

Thanks to the increasing spread of the Internet - even to remote locations - new opportunities for astronomical education are opening up. Even places with very good observing conditions are now often connected to the Internet, including many places that were previously used for astronomical research.

These places often no longer meet the demands of state-of-the-art research, but still offer excellent conditions - and the infrastructure needed to operate a telescope. There is now an increasing number of remote telescopes dedicated to education and citizen science [2].

Remote telescopes in the educational field can either be directly remote controlled or automatically perform observation tasks and provide the images. The former has the main advantage of giving observers more freedom, while feeling more like classical observations. However, one is dependent on specific times, depending on where the telescope is located. In addition,

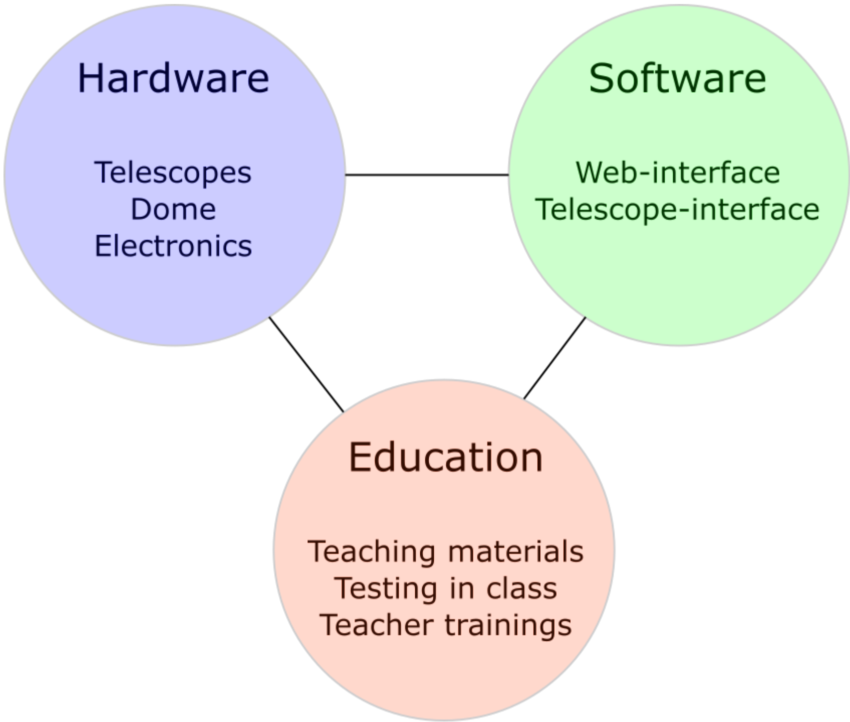


Figure 1: The three fundamentals of setting up a remote telescope in Education.

the observations may take a lot of time. Automated observation is much more efficient, both in terms of telescope utilization and observer time. This procedure also corresponds to the procedure in modern astrophysics. Both possibilities, however, require a certain degree of abstraction from the learners, so that most remote telescopes are rather unsuitable as an introduction to astronomy [3], but offer great potential for more advanced problems, for example in Project-Based-Learning units [4].

First Steps: Conception, Hard- and Software and Money: Building and operating a remote telescope is a big project. With the experience of building a remote telescope in the educational and citizen science area - the Stellarium Gornergrat (https://stellarium-gornergrat.ch/) in Switzerland [5] - some important points to consider are explained here.

The first steps are mostly conceptual and technical, the main aspects can be found in Table 1. After these questions are answered, one must think about the financing. The possibilities range from local sponsors and the local university to national or international donors, although this depends strongly on the respective situation.

From a Remote Telescope to a Remote Telescope in Education: Learners and teachers are not astronomers or astrophysicists, so one cannot generally assume any special knowledge. Accordingly, they need more than just the data, a key element is also provided materials. These enable work with the recordings, providing not only worksheets but also additional texts for the learners and solutions and further information for the teachers. It is important to provide the materials in the native language [6]. The materials should also be adapted to the respective curricula in order to facilitate their use in the classroom.

Additionally, easy access to the telescope is important. Both learners and teachers must be

Points to consider	(Some) Aspects
Control of the telescope	Direct control or automatic observing?
Target group	Primary School, Secondary School, University, Citizen Science, etc.
Expertise in the team	Technical, software, astronomical, pedagogical knowledge
Hardware	Different telescopes (magnification and field of view), dome, weather sensors, server etc.
Software	Remote control of the server, dome control, telescope control, observation control, camera control
Access	Easy control, customizable presets
Materials	Teaching materials, worksheets, further information texts for teachers and students, back-up-data for unsuccessful observation

Main aspects to consider for a remote telescope in education.

able to obtain good images without any special prior knowledge, for example by using preset settings, which however can be adjusted by advanced users.

In summary, a remote telescope in education is therefore also based on three fundamentals: hardware, software and education (see Figure 1). International collaborations with other remote telescopes are recommended, especially during the setup, but also in the long term.

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Management of a Project Involving Observations with Remote Telescopes and Data Reduction

Speaker: Michele Gerbaldi, Institut d'Astrophysique de Paris (IAP), France

In the inquiry-based Astrolab program, undergraduate students plan observations with remote telescopes from Las Cumbres Observatory, and transform them into a scientific result. It is a learning-by-doing tutorial to understand the complexity of practical work through the interdisciplinary aspect of Astronomy. The students take an active role in determining how to collect and analyze data to fulfill the goal of the lab. Thus, students engage more thoroughly in the scientific process. But it is also more challenging for the tutor, as these labs can be harder to supervise. Students lacking experience in the process may require significant coaching and assistance. However, the positive learning experiences are considerable. Therefore, a project management for tutors was developed.

Talk link: https://youtu.be/Y4-Mw-H_TSc

To get undergraduate students involved in science studies, lab activities are a necessity, but often scarce funding limits the capacity to implement it. In that context the enquiry-based lab Astrolab was developed, with support from the Office of Astronomy for Development (www.astro4dev.org), one of the IAU Offices. It is mainly implemented in the Sub-Saharan Africa, but activities in Peru and Nepal are starting up.

The tutorial has primarily been developed for undergraduate science students in order to emphasize the interdisciplinary nature of astronomy, and its natural links with technology and instrumentation.

In doing Astrolab, students in sciences plan and perform real-time observations with remote/robotic telescopes, and transform those observations into a scientific result. It is a learning-by-doing tutorial to acquire research competences and to understand the complexity of practical scientific work.

The access to a telescope is the core for this program. The remote telescopes used are those from the Las Cumbres Observatory (https://lco.global/). Telescope time has been granted through the Global Sky Partners program. 10 telescopes of 40 cm can be used located in both the Northern and the Southern hemisphere. Altogether, the allotted time covers about 20 hours of possible continuous observations.

The challenge for students in the project is the planning of the dates of the observations to enable them to construct the light curve from the data obtained, taking into account the period of their target. This is the most difficult part of Astrolab as the knowledge of the student on periodic phenomena is essentially limited to oscillating functions. The students know such variable phenomena from electromagnetism studies. The rich pedagogical aspects of the astronomical variable phenomena are often neglected.

However, for eclipsing variable systems the concept of Ephemerid is an obstacle and requires understanding. Indeed, to fix the observational dates the student has to understand the meaning of the Ephemerid of a periodic phenomenon in astronomy to perform observations at well-chosen dates to cover the phase at best. It means understanding the relation between the phase, the date of a potential observation in Julian Date, and the civil date, and the accessibility of the telescope at that date, including the Moon phase.

In Astrolab, the students have an active role in determining which eclipsing binary system to observe, how to collect and how to analyze the data. This engages the students more in the scientific process, but it is also challenging for the tutor.

As the students lack experience in this process, it requires significant coaching and assistance. However, the positive learning experiences are considerable. Consequently, an Astrolab project needs educational management.

The learning process runs from idea to conclusion: Starting from basic principles of astrophysics, we let young people discover the thrill of doing science by going themselves through the complete research cycle, including hands-on observations planned by themselves.

The tutoring is not monitoring. The management consists of careful supervision, respecting the students' previous undergraduate knowledge in STEM activities.

Just an example of the difference between Monitoring and Supervising for telescopic observation. In Monitoring: pre-designed observations of pre-selected objects are given. In Supervising: the tutor will guide the student to select the "best" target in the framework of her/his timetable, by asking questions or making comments, but not giving a solution.

Therefore, the management process of the project requires the supervisor for each student to:

- verify that all aspects of the student project are on track, according to agreed plans and schedules (often imposed by the university calendar)

- verify the data collected by the student: the student must have the habit to check each image as soon as taken, not to accumulate the images till their analysis

To conclude, project management enhances student engagement continuously. The effectiveness of the project lies in the supervising challenge. The tutorial is based on computer games characteristics that attract but are difficult to manage: autonomy, possibility of failure, learning by doing.

The supervision requirements, detailed above, apply evenly well to inquiry-based activities at high school level.

Engaging Young Audiences in Remote Observing: A Case Study with "Serol's Cosmic Explorers"

Speaker: Alice Hopkinson, Las Cumbres Observatory, UK

Currently, many robotic telescope projects require prior astronomy knowledge and scientific skills. These investigations appeal mainly to older students. Reaching younger audiences requires a different approach. One technique is to introduce remote observing and astronomy through interactive challenges and character-based narrative. Journeying through missions with clear goals and simple follow-up investigations makes observing accessible to new audiences. Incorporating many materials - such as videos, workshops and games - can create a cohesive, simple and fun environment for learning. In this talk I will discuss the practical elements of this approach, using our project "Serol's Cosmic Explorers" as a case study.

Talk link: https://youtu.be/HPMMe-tHYMU

In general, many education projects using robotic telescopes are aimed at older students. These projects are often research-based and technically complex. However, robotic telescopes provide opportunity for hands-on experience with astronomy that can also inspire and benefit younger audiences. Enabling children to take their own pictures of space can give a sense of agency in astronomy learning which leaves a lasting impression.

At Las Cumbres Observatory, Serol's Cosmic Explorers (serol.lco.global) is an education program we created to make robotic observing accessible and enjoyable for children and audiences without prior astronomy knowledge. The key points of the talk are as follows and are summarised in Figure 1.

Do not assume knowledge: Primarily, we cannot assume any prior knowledge of the subject. Explanation of the observing process should be kept simple and enjoyable.

Clear structure: The observing program should be clearly structured, whilst still giving the user some agency. With Serol's Cosmic Explorers, we provided structure through missions and challenges. The missions grouped astronomy themes, and the challenges focused on specific astronomical objects within each theme. The user is still given some agency within this structure through choices such as the target to capture.

Guided analysis: Including guided analysis after the user has received their image can help them learn more about the object they have captured. In Serol's case, we guided the analysis through questions and multiple choice answers. In this way, encouraging the user to consider certain aspects within their images can help them to start thinking scientifically about these observations.

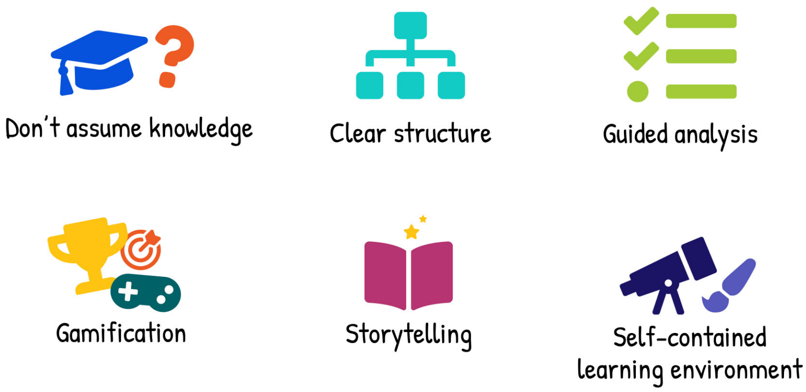

Figure 1: A summary of the key points to consider when creating a remote observing program for young audiences.

Gamification: To further increase engagement and retain the interest of a young audience, you can incorporate some aspects of gamification. For Serol, we used badges, with a new badge unlocked after every challenge is successfully completed. We included a progress page to view all badges obtained as well as an option to review all images taken. In general, you want project rewards to excite the user so that they remain engaged in learning.

Storytelling: It can be engaging to use storytelling, for example through video animation, as a way to disseminate important information relating to the topics of your project. Using anthropomorphised characters in these stories can be particularly engaging for children. As an example, we created animated videos that help set the scene for the missions the user will undertake. These stories and the theme of the observing process all work together to create a friendly atmosphere that encourages exploration, and frames learning and observing as a fun journey.

Self-contained learning environment: Lastly, it is helpful to place the observing project in a self contained learning environment, where everything needed is readily available in one place. For younger audiences, combining narrative content with practical tasks for the project can provide a cohesive and enjoyable learning experience. Incorporating multiple mediums for learning can further improve this self-contained educational environment. To meet this need for Serol, alongside the observing missions and the videos, we also included printable activities such as 3D models and colouring sheets, a video game, and workshops.

Things that Stop Teachers Doing Robotic Astronomy Education

Speaker: Michael Fitzgerald, Las Cumbres Observatory, California and Deakin University, Australia

Teachers are the gatekeepers of access to students and also direct activity undertaken by students in the classroom. If we are to embed this technology into schools beyond the gifted and talented, we need to address the needs of everyday teachers. These needs are amplified for schools in poorer, rural and under-served communities. In this talk, research on the needs and blocking factors identified by teachers for robotic telescopes usage are outlined and some examples of how to address these needs are identified. This talk is particularly suited to projects attempting to engage multiple schools.

Talk link: https://youtu.be/W2Jp7YpRm0I

STEM Education with Robotic Telescopes: Lessons from a Multi-approach Project

Speaker: Nayra Rodríguez Eugenio, Instituto de Astrofísica de Canarias (IAC), Spain

Within the field of educational projects with robotic telescopes there is a variety of approaches: activities or research projects with pre-observed data, pre-designed observations of selected objects, guided research projects and authentic astronomical investigations, using either remote-controlled or automatic observations. The Educational Project with Robotic Telescopes (PETeR) of the Instituto de Astrofísica de Canarias offers all these types of models through collaborations with institutions owning robotic telescopes. In this talk I will review the advantages and disadvantages that we have identified of each approach, the type of user that prefers each of them, and the resources, training and support that users of educational projects require to be able to develop them effectively.

Talk link: https://youtu.be/v0hs9_dabt4

When setting up an educational project with robotic telescopes, we must consider which format is best suited to the specific needs of our target audience, the objectives pursued and the resources available: telescopes and instrumentation, amount of observation time, staff dedicated to the project, etc.

The IAC is a Spanish R&D center in astrophysics that operates the Observatories of the Canary Islands, which host the telescopes of some 60 institutions from more than 20 countries. Thanks to the Agreements on Cooperation in Astrophysics [1], the IAC receives a percentage of the observing time on these telescopes and, in 2004, decided to allocate part of its guaranteed time on some robotic telescopes to education. To this end, the IAC created the Educational Project with Robotic Telescopes (PETeR) [2], an online inquiry-based lab that allows schools to carry out their own observations and research projects in astronomy. The availability of observing time on several telescopes, which also offer different types of observations through user-friendly portals, has allowed us to open the project to the entire Spanish educational community, from primary to secondary school and vocational training.

Our users, regardless of their educational level, have access to the full set of resources and educational approaches we offer: pre-defined observations of selected objects, activities and research projects with pre-observed data, guided research projects and open astronomical investigations, using both automatic and remote-controlled observations. This makes PETeR a unique laboratory to evaluate the suitability of each of these models to the type of user, as well as their strengths and weaknesses.

Approaches:

Pre-defined Observations: Our model consists of obtaining and analyzing one- or three-color images of different types of objects that can be selected from a list. The observing interface sets, for each object, the appropriate instrument, filter(s), and exposure time. Therefore, this is the easiest option to integrate into teaching practice, as it requires less prior knowledge and is less time-consuming.

For this approach we use the Liverpool Telescope and the observing portal of the National Schools' Observatory (NSO) [3], which allows observations of regions of the Moon, planets, nebulae, stellar clusters and galaxies, and also provides information about the selected object. To visualize and analyze the images, software specially designed for education is also offered.

This experience can be carried out on its own or integrated into a research project, and is mainly chosen by primary and secondary school teachers with little or no previous experience in astronomy. The major weakness of this approach, when undertaken as a stand-alone activity, is that it does not involve an inquiry-based learning process by itself.

Didactic Units: Each Unit introduces several astronomy concepts related to primary and secondary school curricula, and provides one or more practical activities, which make use of pre-observed data and serve as a practical introduction to the different tools of the image processing software.

Didactic Units are designed for structured or guided inquiry, but can serve as a first step in an authentic research process by complementing the activities with the planning, acquisition and analysis of new observations, either pre-defined or open-ended.

The type of users who tend to choose this format are 5th-6th grade primary teachers (8-10 year old students), secondary school teachers of STEM subjects with no or little previous experience in astronomy, and also high school astronomy clubs.

Among the advantages that our users highlight about this approach are that it does not require previous knowledge of astronomy, and that they do not have to spend a lot of time on preparation because the teaching materials are already adapted to the curricular contents.

Guided Research Projects and Open Astronomical Investigations: These approaches correspond to authentic research processes, either guided or open inquiry. In the first case, we propose to the teachers the type of research to be carried out and the possible methodology to follow to select the objects, observe them and analyze the data obtained. Some examples of guided research projects we offer are the characterization of variable stars and exoplanets with transits, the detection of Supernovae, and the confirmation of asteroid orbits. In the open approach, it is the group of students plus teacher who decide what they want to investigate. In both cases we provide scientific and technical advice when required.

The open observations required for these types of projects can be performed directly by our users through the observation portal of Las Cumbres Observatory (to which we have access through the Global Sky Partners program [4]), The Open University's public portal [5], and the advanced interface of the NSO portal. They can also be done remotely and supervised using the SARA telescopes [6].

These projects are usually developed by teachers who attend our specific training courses. In these trainings they learn basic concepts of astronomy and telescopes, how to use the observation portals of the different telescopes, how to work with astronomical images, and they also develop some of the activities and guided research projects we offer.

The strength of these approaches is that students experience the scientific process in all its phases. And the disadvantage would be in the time required both from teachers, who have to be trained beforehand, and from the project coordinator, since it is normal for schools to request individualized advice at some point.

Teachers who participate in PETeR and attend our training courses highlight the enormous potential of these approaches to develop active learning in STEM areas, and to foster scientific thinking in their students and collaborative work.

References:

1. https://www.iac.es/sites/default/files/documents/2018-05/intergovernmentalagreement.pdf

2. PETeR website: www.iac.es/peter

3. National Schools' Observatory website: https://www.schoolsobservatory.org/

4. LCO Global Sky Partners website: https://lco.global/education/partners/

5. OpenScience Observatories (OU) public observing portal: https://www.telescope.org/

6. The Southeastern Association for Research in Astronomy: https://www.saraobservatory.org/

Broadening Participation in Remote Observing: Strategies Gleaned from 25 Years of MicroObservatory

Speaker: Mary Dussault, Center for Astrophysics | Harvard & Smithsonian, USA

Collaborators: Alaalden Ibrahim, Frank Sienkiewicz, and Erika Wright (Center for Astrophysics | Harvard & Smithsonian)

The Micro Observatory telescope network has been in continuous use by hundreds of thousands of learners worldwide since 1996. From more than 2 decades of research and development facing many challenges and some success, we report on: 1) findings from research that provide actionable evidence for what works; 2) some new tools and promising techniques (ours and others') for engaging new audiences in remote observing; 3) a practitioner's perspective on how and why the incredible potential of authentic STEM learning through remote astronomical observing platforms has not (YET) been realized; and 4) how participants in this IAU workshop can help to meet this potential through the broadening of participation to communities of learners that have been marginalized from deep STEM engagement

Talk link: https://youtu.be/D16P1L5aTAw

Session attendees may find the following resources useful. Most are referred to in the talk.

Relevant Articles, Actionable Findings – What Works?:

- Gould, R. Dussault, M. & Sadler, P.(2006). What's Educational about Online Telescopes?: Evaluating 10 Years of MicroObservatory. https://access.portico.org/Portico/show?content=E-Journal%20Content&cs=ISSN_15391515&auId=ark%3A%2F27927%2Fpgg3ztfbdch&auViewType1=PDF - 15 years old, but still some relevant insights and information.

- Gomez, E. L., & Fitzgerald, M. T. (2017). Robotic telescopes in education. Astronomical Review, 13(1), 28-68. https://www.tandfonline.com/doi/pdf/10.1080/21672857.2017.1303264 - An article everyone interested in this session should read.

- Krumhansl, R., Busey, A., Krumhansl, K., Foster, J., & Peach, C. (2013, September). Visualizing oceans of data: educational interface design. http://oceansofdata.org/sites/oceansofdata.org/files/Visualizing-Oceans-Data-Report-Dec2013.pdf - An incredibly useful set of research-informed guidelines.

- Schibuk, E., Wright, E., & Dussault, M. E. (2020). Illuminating the Universe. Science Scope, 43(9), 22-31. https://www.nsta.org/science-scope/science-scope-julyaugust-2020/illuminating-universe - A Boston teacher's description of YouthAstroNet in action.

MicroObservatory Links:

- MicroObservatory: https://mo-www.cfa.harvard.edu/MicroObservatory/

- Observing With NASA portal to MicroObservatory: https://mo-www.cfa.harvard.edu/OWN/

- DIY Planet Search portal to explore exoplanets: https://waps.cfa.harvard.edu/microobservatory/diy/index.php

- YouthAstroNet Program: https://www.cfa.harvard.edu/research/youthastronet

- YouthAstroNet poster of preliminary research findings (findings presented in talk are yet to be published): https://mo-www.cfa.harvard.edu/OWN/pdf/YAN_Poster2017_AAS.pdf

Promising Tools and Techniques:

- Messier Bingo — first step engagement for novice observers from Las Cumbres Observatory — https://messierbingo.lco.global/

- Browser-based Image Analysis Tools: Js9 (created by developers of DS9) https://js9.si.edu/, Js9-4L ("for Learners" – Js9 adapted for MicroObservatory users) https://waps.cfa.harvard.edu/eduportal/js9/software.php, Afterglow Access (created by IDATA project in collaboration with Skynet @ UNC): https://idataproject.org/resources/ and https://afterglow.skynetjuniorscholars.org/

- Exoplanet Watch – "next step citizen science engagement" for robotic telescope users. https://exoplanets.nasa.gov/exoplanet-watch/

Broadening our Perspective on Broadening Participation: Bevan, B., Calabrese Barton, A., & Garibay, C. (2020). Broadening perspectives on broadening participation: Professional learning tools for more expansive and equitable science communication. https://www.informalsc ience.org/broadening-perspectives *A STEM Toolkit from the Center for the Advancement of Informal Science Education (CAISE), to help STEM education practitioners and science communication groups reflect on and strengthen their efforts to broaden participation.*

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The HR Diagram with Remote Telescopes at LCO

Presenter: Priya Hasan, Maulana Azad National Urdu University, India

With the lack of dark skies, the pleasure of doing astronomical observations with telescopes has been very strongly affected. The experience of obtaining live astronomical data is a very important step in Data Analysis. In partnership with the Las Cumbres Observatory, we are training students to observe star clusters, open and globular. We teach them processing of the images and photometry. They finally make Hertzsprung-Russell diagrams of the clusters to study stellar evolution.

Poster link: https://youtu.be/rilSSDrM_dc

The Las Cumbres Observatory has a set of 0.4m robotic telescopes placed all over the world. We, as Shristi Astronomy are Global Sky Partners and have access to these telescopes. We also have an ongoing IAU-OAD Project "AstroSprint" which is a guide to projects using archival data in astronomy. The purpose of this work is to provide hands-on experience to students in astronomical data from telescopes.

Star clusters are groups of stars that formed from the same molecular cloud, at the same distance, of the same age, varying only in mass. They are unique objects for which we can find stellar parameters using the Hertzsprung-Russell diagram. We will train students on the fundamental concepts of photometry, magnitude scales, airmass, stellar evolution and the HR Diagram. We shall also submit observation proposals and train students to do photometry and plot HR diagrams.

The Sky at Your Home: Remote Observing Talks to the Public while Observing the Sky

Presenter: Josina Nascimento, Observatório Nacional / Ministério da Ciência, Tecnologia e Inovações, Brazil

Collaborators: Ricardo Ogando, Alba Lívia Bozi, Eugênio Reis (ON/MCTI), Leandro Guedes, Wailã Cruz (Planetário do Rio), Wagner Corradi, Mariângela Oliveira-Abans, Adriano Messala, Saulo Gargaglioni (LNA/MCTI), Claudia Mattos (MAST/MCTI), Gabriel Hickel (UNIFEI), James Solon (AstroPE), David Duarte, Romualdo Caldas (CEAAL/UFAL), Marcelo Domingues, Maciel Sparrenberger(CASB), Erick Couto (AstroAra), Ariel Adorno de Sousa, Jean Carlos Rodrigues (CAR), José Carlos Diniz (CANF), Sérgio Lomônaco (NGC 51/Espaço Ciência Viva), Carlos Palhares (Observatório Zênite), Heliomarzio Moreira, Ednardo Rodrigues (Seara da Ciência/CASF), Daniel Raimann (UDESC Oeste/Apontador de Estrelas), and Thales dos Santos (Clube de Astronomia de Roraima)

Opening domes and offering the sky through telescopes has always been one of the moments of greatest encounter between researchers, students, educators, family members and for everyone who wants to know a little bit about the universe. Because of the pandemic caused by SARS-CoV-2, we teamed up with amateur astronomers from various locations in Brazil, which is vast in latitude and longitude, to show the sky through their telescopes. Since June 2020 until now they have formed 19 remote observation lives of the sky, where we show the moon, planets, star clusters, nebulae, galaxies and comets.Both amateur and professional astronomers are involved in the project and some of them are teachers as well.Lives last about four hours and have hundreds to thousands of people watching and interacting.

Poster link: https://youtu.be/zpQ8OL6-1oA

The Observatório Nacional (ON) is one of the oldest scientific institutions in Brazil. Among our events, one of the most beloved attractions is when the students, educators and the general public gets to observe the sky alongside the researchers, which brings about a great deal of connection between both parts. When the SARS-CoV-2 pandemic came about we could no longer be with our beloved public, so we started promoting online events in our social media. In April 2020 we started to seek out partnerships with amateur astronomers throughout the country and, in June of that same year, we held our first virtual meeting with the public in the project "The sky at your home: remote observation", in which we streamed live the sky while talking to the public, just as we had always done when meeting face-to-face. Later on, professional astronomers and astrophysicists as well as elementary and high-school level teachers joined the project. This greatly enlarged the scope of the project and reinforced national integration.

At 16 months old, the project has had 20 editions, one each month and 4 special editions. Live Streaming has been such a wonderful experience for all of us that we have not been able to keep it under 4 hours. Those have been lovely hours that we spend together, showing the sky and talking about the astronomical instruments, formation of the Universe, the evolution of stars,sky phenomena, light pollution, sky by different cultures and so many other subjects that the public bring to the conversation. The fact that our partners are spread out geographically over the entire country allows us to show the same phenomenon from different angles. We have also made possible that a phenomenon would be seen in real-time even when impossible for a certain place, due to either weather instability or simply not being night in that area while the event was taking place.

The live streams recorded on our YouTube channel, allowing people to watch them even after the event. A typical live stream ends with about 1 to 2 thousand views and usually gets up to 10 thousand views afterwards, but the live streaming of the Mars occultation by the Moon (9/5/2020), the conjunction of Jupiter and Saturn (12/21/2020), the Total eclipse of the Moon (5/26/2021) and Annular eclipse of the sun (6/10/2021) has, respectively, 44, 265, 73 and 13 thousand views. These eclipses were not visible from Brazil, but we started live streaming from other areas of the planet at 5 am. On both occasions, teachers joined us with their students. That was fantastic! This project has been of utmost importance to educators, students and their families, as said spontaneously by the attendees themselves, as well as neuro-pedagogues who work with special education. It will have its continuity guaranteed even when face-to-face activities return, due to its unprecedented success and reach.

Appreciate the Awesomeness of the Universe

Presenter: Eamonn Ansbro, Kingsland Observatory and Space Exploration Ltd., Ireland

Students can be encouraged to astronomy by what I call the 'Amazing Astronomy Program Initiative'. It is important that students own projects and feel connected in an exciting new way of using remote observing. Students carry out astronomy observations and research projects using robotic telescopes from there schools and colleges. Projects of interest can be adaptable with hands-on activities focusing on concepts in astronomy, digital imaging, light & colour, etc. These elements alone are designed to support authentic inquiry: e.g., requesting images with a robotic telescope; using image processing software to enhance and make measurements of images; asking questions; connecting science to everyday life.

Poster link: https://astro4edu.org/siw/p68

Awe of the Universe: Awe is felt when our mind begins to comprehend something that we did not comprehend before. This can be as simple in marvelling at the immense expanse of space, pointing a telescope towards the sky to capture galaxies, nebulae, and star clusters. Students' images stay with them and bring a feeling of greatness whenever they need.

Every child at some stage is in awe with the universe. Students can be encouraged to astronomy by what I call the 'Amazing Astronomy Program Initiative'. It is important that students own projects to discover the universe and feel that connection and excitement in a new way of using remote observing.

Owning the telescope requires immersion: The main key tool in remote observing is the telescope. The telescope, although remote from the classroom, should be presented as not just a tool to request images, but an integral experience of using the telescope that feels fun to use, so the student is fully immersed. This approach is different from the conventions in protocols for remote observing.

Technology and Vision: The use of recent vision technology significantly provides a reality that is not normally provided in conventional remote observing. The idea is for the student to own both the telescope and a suggested project. We emphasize real vision when using our telescopes. This means that the observer is connected to the telescope with a vision system that portrays itself as if the observer is within the observatory. This way the experiential connection becomes a new experience than the conventional disconnection as if the telescope is remote and does not feel real to the student observer.

The observer operates the telescope similar to a flight pilot's cockpit. Multiple cameras achieve this goal. Motion detection synchronises the camera with the telescope movement, so the pilot has the controls, has the visual front view of the scene. This provides the special, emotional aspects, providing "spatial" experience similar to real world experience and therefore a spatial cognitive experience. This leads to more excitement because of initiating this awe.

Connectivity and authentic inquiry: Students carry out astronomy observations and research projects using robotic telescopes from their schools and colleges. Projects of interest can be adaptable with hands-on activities focusing on concepts in astronomy, digital imaging, light & colour, etc. These elements alone are designed to support authentic inquiry: for example, requesting images with a robotic telescope; using image processing software to enhance and make measurements of images; asking questions; connecting science to everyday life. In this way, you can enable them to participate and experience the thrill and excitement of scientific observation and discovery.

Discussion summary

Both remote observing sessions were followed by live discussions with the speakers going deeper in the topics addressed during their talks and following up with questions and comments presented by the public.

It was a consensus that remote observing based projects have an enormous potential to engage students in science, but need to be constantly improved in order to serve more people, mainly those in underprivileged areas and countries.

Funding opportunities were therefore addressed as a bottleneck for long term observing projects, making it difficult to scale the projects at national or even international levels. Nevertheless, it was reminded that some projects are for free or at low-cost for the participating schools and therefore, opportunities are available to engage in such projects.

Another topic discussed concerned how to start engaging with remote observing projects. For education use, it seems to be a consensus that the best thing to do is to engage with the Las Cumbres Observatory through the Global Sky Partners program: `https://lco.global/education/partners/`. Nevertheless, all speakers mentioned that those interested in joining remote observing projects should get in contact to start a conversation. Another point raised by the attendees was that it would be useful if there was a master catalog listing the available remote observatories. It was mentioned by the speakers, however, that there were already attempts in this direction, but it is hard to keep these lists up-to-date. Big projects, such as Las Cumbres Observatory, SkyNet and iTelescope, tend to keep their data updated, which might not be the case for the smaller ones.

Finally, another topic addressed by the panelists concerned the need of having educational material in different languages, which could benefit many teachers and students. As for now, most material is in English, some in Spanish and even fewer in other languages. Preparing all the material in multiple languages is not that straightforward, but definitely something to be pursued in the future.

Student Competitions

Session organiser: Aniket Sule,
Homi Bhabha Centre for Science Education
(HBCSE-TIFR), India

Session overview

The session on the student competitions was focussed on discussing the role of competitions in the life of school students. School level student competitions come in different forms. Some competitions like Olympiads give importance to challenging problems and invite the brightest students to solve them in a time bound manner. Some other competitions invite students to participate in small research projects. Such projects can be in the form of building a small gadget or can be collecting data from a simple experiment or preparing a detailed plan proposal for a futuristic idea. There are also a number of outreach oriented competitions, like astronomy themed drawing / photography contests, theater performances or quizzes. These types of competitions pique student interest in Astronomy.

In order to cover this wide spectrum of competitions, the academic committee of the session chose five speakers. Greg Stachowski, who is the president of the International Olympiad on Astronomy and Astrophysics (IOAA), spoke about motivation behind the organisation of Astronomy Olympiads as well as positive outcomes of these competitions. Josina Nascimento, who has worked with the Brazilian National Astronomy Olympiad for a number of years, spoke about how a national astronomy Olympiad programme can create a large participation base across the country covering the majority of schools and support inclusive practices. Ioana Zelko, who was a student participant in multiple international Olympiads and is currently a mentor for USA Astronomy and Astrophysics Olympiad, talked about the role Olympiads play in the life of a student and how it can motivate students to take a serious look at a career in astronomy research. Danijela Takač, who - as a school teacher - has worked with the Croatian National Astronomy Olympiad for a number of years, talked about how mini research projects by school students can be part of national Olympiads and what value such open ended exercises offer to students. Lastly, Olayinka Fagbemiro, who volunteers for Astronomers Without Borders in Nigeria, spoke about an art competition for school students, which unleashed students' creativity and opened a window for adults to get a glimpse of students' ideas about space and astronomy.

The Purpose of Olympiads

Speaker: Greg Stachowski, Pedagogical University of Cracow, Poland

Science olympiads are a form of intellectual competition for school students originally inspired by the sports Olympics, and just like in sports they can motivate young people and provide a framework for them to learn and grow. In this talk I will briefly explain the International Olympiad on Astronomy and Astrophysics and how it (and national level competitions) can help education by inspiring students, as a resource of educational materials for teachers and as a means to connect students and teachers with amateur and professional astronomers.

Talk link: https://youtu.be/NHFXYHmfbTc

In this talk I would like to introduce the guiding principles behind olympiads, show how they can help with education in astronomy (and by extension in other STEM subjects) and explain how an event such as the *International Olympiad on Astronomy and Astrophysics* works.

The name "olympiad" was deliberately chosen by the founders of the first 'intellectual' olympiads in the early 20th century to evoke the spirit of the sporting Olympic Games. To quote the International Olympic Committee:

"The goal of the Olympic Movement is to contribute to building a peaceful and better world by educating youth through sport practiced without discrimination of any kind and in the Olympic Spirit, which requires mutual understanding with a spirit of friendship, solidarity and fair play."

Today the olympiads which descend from those early events aspire to the same ideals. They are competitions, but organised with the aim of motivating young people to learn and develop and do so in friendship with their peers from around the world. So how do olympiads achieve these goals? First, by channelling the natural competitiveness of young people towards learning. Rewards (progressing through different levels, receiving medals or prizes) is based primarily on personal achievement rather than 'overcoming' someone else.

Second, the syllabus and questions in olympiads go beyond the school curriculum. Students who want to participate have to learn and think independently, read more widely and practice their chosen subject. They have to develop not just problem solving skills but also learn how to seek out information and manage their time.

Third, olympiads bring together students with a shared interest from different places, across regions, across the nation or internationally.

When it comes to learning astronomy, olympiads are particularly useful because there is often very little astronomy in the school curriculum in many countries. More generally in STEM subjects,the curriculum often lags behind the latest research. Textbook problems are often theoretical or use artificial data to give the expected answer. In such cases the curated syllabus of an olympiad can be useful to students and their supporting teachers in learning astronomy. They get to solve more stimulating problems involving recent research, can perform their own observations and interpret real data, using approximation methods, iteration, error analysis and statistics - topics which are often underrepresented at school level.

Aside from this, students who participate in olympiads may be eligible for benefits such as tuition grants or university entry points, depending on their country. From the point of view of preparing a team to participate in an olympiad, training programs can easily be expanded to include more students than just the team, spreading the benefits to a wider group. Teachers also benefit from the resources which olympiads prepare. The syllabus and past papers are available and can supplement textbooks. Papers from international olympiads are translated into the languages of the participants and made freely available together with model solutions, which can be a great resource especially in countries where astronomy textbooks in the native language are not common. Several problem books have also been published in a number of languages which include a wider discussion of questions.

Finally, teachers who participate in training their students or who attend olympiads as team leaders come into contact with amateur and professional astronomers and planetarium staff, which gives further opportunities for expanding astronomy education at the school level. In turn professionals can better understand the needs of teachers and students when thinking about outreach. Participating in an olympiad can also convince students (and their parents!) that studying astronomy is a worthwhile career like, say, engineering or medicine.

Olympiads attract the attention of the media and government. This can lead to more resources and better public knowledge of astronomy. National and regional olympiads and workshops have been organised thanks to this attention and a junior International Olympiad is in the works. The physical resources from olympiads such as telescopes can also be distributed for use by schools after the event. To show how an olympiad is organized we can look at the International Olympiad on Astronomy and Astrophysics (IOAA). This has taken place since 2007 and teams from about 50 countries participate, each with 5 students and 2 adult team leaders. The host country provides all accommodation and living expenses as well as cultural events, while the teams pay for their travel. During the IOAA there are three individual rounds: theoretical, data analysis and observation. There is also a team competition, and an (optional) poster competition. Questions are vetted by the team leaders. Awards are given for achieving an objective score rather than being ‘first’. Social and cultural events take place between rounds.

The theoretical round consists of classical problems: derivations, formulae and concepts, all solvable without calculus as this is not in the curriculum in many countries. The data analysis round involves real data, including measurement errors and outliers, from which the students obtain realistic results using a variety of methods. The observation round can involve any combination of naked-eye, telescopic or simulated observations and tasks such as identifying objects, measuring positions and sizes or timing events.

The team competition mixes students from different countries, encouraging them to work together much like a real research group. The tasks are designed so that all members can contribute and this is often where students without practice at 'exam technique' can achieve good results. Finally the poster competition gives students an opportunity to showcase their out-of-Olympiad astronomy interests through conference-style posters.

In summary, olympiads are competitions which follow the ideals of the Olympic Movement. They can provide students and teachers with an introduction to the wider field of astronomy and astronomy practitioners beyond the school curriculum, and should be thought of as another tool for our common goal of improving and propagating education in astronomy.

Building up a National / Regional Talent Nurture Program through Competition

Speaker: Josina Oliveira do Nascimento, Observatório Nacional – ON/MCTI, Brazil

Collaborators: João Batista Garcia Canalle (Instituto de Física – IF/UERJ), Eugênio Reis Neto (Observatório Nacional – ON/MCTI), Gustavo de Araújo Rojas (Universidade Federal de São Carlos), José Bezerra Pessoa Filho (Instituto de Aeronáutica e Espaço – IAE/MD), Júlio Cesar Klafke (Universidade Paulista – UNIP), Thiago Paulin Caraviello (ETAPA)

The Brazilian Astronomy and Astronautics Olympiad (Olimpíada Brasileira de Astronomia e Astronáutica; OBA) is an annual national educational competition inaugurated in 1998 and currently in its 24th edition. Its main goal is to improve science education using astronomy and astronautics as motivators. As a consequence, it increases the students' interest in these subjects. Despite not being part of the national school curricula, astronomy's appeal as a fascinating and multidisciplinary science act as a catalyst to bring students and teachers alike closer to other sciences, such as mathematics, physics, and chemistry, and other disciplines like geography, history, philosophy, and arts. One may question how a competitive event such as an Olympiad can foster the rise of new talents. Part of the answer lies in the strategies employed to attract and capacitate teachers from all school levels. We will also show how we have successfully reached teachers and students from all states in Brazil and how the wide-ranging award scheme stimulates the emergence of new talents.

Talk link: https://youtu.be/_n2CoPt5crE

The first factor that contributes to the formation of national talents is the innate objective of the olympiad, which, since its conception, has been much more than a competition, but rather a way of piquing the interest of the children and the young in science. OBA was intended to be used as a pedagogical resource, an instrument that, much more than awarding the best students, reached the objective of captivating the interest of the younger population in science. The exam should be interesting and designed in a way that aims to not draw back the student due to lack of necessary knowledge. Without a doubt, the event could serve also to reveal young talents, promote astronomy and unite people that worked in the teaching and popularization of astronomy [1].

The second factor is the reach of the olympiad since the first year of elementary school, when children are still learning to read. The exam is presented through simple phrases and images that lead the student to think about the nature in which they live.

The third point is the structure of the exams. The exams are applied at 4 different levels according to the school year, from elementary school to high school. The olympics exams themselves are moments of learning. The questions bring specific knowledge and motivate the student to develop the rationale using the other curricular course contents as base.

The fourth factor is fundamental for the success of this enormous action and consists of the capacitation and constant communication with the professors. Since 2009, OBA has promoted the EREAS (Encontro Regional de Ensino de Astronomia/Regional Meetings of Astronomy Education) aiming to capacitate elementary, middle and high school teachers in astronomy education, with 78 meetings to date. Other actions have arisen in several parts of the country having the Meetings as inspiration, with the two projects dedicated mainly to the continued formation of the teachers, but also with actions along with students. They are "Olhai pro Céu" / "Look Up at the Sky", which is a project in partnership with the (ON) (Observatório Nacional/National Observatory) and the MAST(Museu de Astronomia e Ciências Afins/Museum of Astronomy and Related Sciences) in Rio de Janeiro and "AstroEducadores" (AstroEducators), which is an online platform of national reach.

The Meetings EREAS and Look Up at the Sky are not happening during the pandemic caused by the new SARS-CoV-2 coronavirus, but the AstroEducators modules are occurring, since such project was already designed in 2013 to be a remote course, with tutoring and always with development of activities that can be reproduced in the classroom.

The following books were distributed broadly and free of charge to schools throughout Brazil: "Astronomy Guide: Continued Graduation of Teachers" [2] and "Astronomy and Astrophysics" [3]. Besides, in its homepage [4], OBA publishes an ample volume of didactic material and explanatory videos with the proposed activities for teachers to develop with their students. Using social media and digital communication tools, OBA is in constant contact with the teachers, as well as with the students.

The fifth factor is related to the broad awarding to students and the motivation for award ceremonies. In the last year of in-person exams, in 2019, the 22nd edition of OBA had 884,979 students distributed through 9,965 schools. 49,648 medals were awarded, as well as certificates for all the students, teachers and schools [5].

The sixth factor is related to the effect of vectorization, since groups of talented students, who won OBA medals, have been organizing informal groups to prepare new students to join and win their own OBA medals. Along the same lines, students who were selected to participate in Brazilian teams at the international olympiads have volunteered to prepare the next teams. Certainly, OBA has been contributing to the success of many students, seeing as many of the medalists receive scholarship offers, either partial or whole, from excellent private schools. Others, after concluding high school, were accepted by renowned international universities, such as MIT and Harvard University. More recently, some Brazilian universities are also reserving spots for the olympic medalists

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Competitions from the Perspective of a Student

Speaker: Ioana Zelko, University of California Los Angeles, USA

Competitions create an educational opportunity for students of all backgrounds. In this talk I will discuss data that shows that by participating in competitions, students can learn to feel like scientists, get to know interesting peers from other countries, learn from each other, solve fun challenges, learn the value of teamwork, and have an overall fun and rewarding experience. Awareness of the existence of the competitions can motivate a student to start learning the subject, and good results in competitions have resulted in college admission and retention of interest in research.

Talk link: https://youtu.be/m4wIHGiSwE0

This talk will discuss four aspects of the competitions from the perspective of a student. First, I will do a brief summary of what the "process" looks like from the perspective of a student, with training and participation. Then I will discuss the impact on education, and community building. Finally, I will conclude with the contributions of competitions to research retention.

Let us start with the competition "process" as seen from the perspective of the student. The first and sometimes most important step is awareness of the subject and the existence of the competition, combined with motivation to participate. Very often, students have never heard of the astronomy or astrophysics competitions, and they may not be aware of what the field is about, or what the problems and questions in the field are like. Letting students know about the existence of the competition is a very important part of the process. The other key ingredient is motivation. Students need to be able to visualize themselves participating, and to know the benefits in doing so.

The next stage is the training. The training process varies based on opportunities available to the students, such as the existence of local teachers and clubs. However, all the materials required by astronomy and astrophysics competitions are readily available online. This gives a student the chance to successfully train, if given the time. Independent study can often be sufficient, and self-studying students have excelled in the competitions very often.

The next step in the process is participating in the competitions themselves. Often, the competitions have different levels, such as local, national, and international. After participating in a stage, the students return to training, either in preparation for the next stage (if they qualified), or for the next year's edition. This cycle allows them to chisel their skills in the subject.

Finally, in the last step, participating students graduate high school and become alumni of the program.They often form a support network for students, as well as peers during the next levels of studies, up and beyond the PhD level. In addition, they often give back to the high school competition programs by volunteering to train younger students and help with the organisation of the program.

Perhaps the most important aspect of the high school competitions is their impact on education. This survey shows the responses of 82 student participants in the Global e-Competition on Astronomy and Astrophysics, an online high school competition that was conducted in 2020 to replace IOAA during the pandemic. The overall picture reflected in the answers was that the students had a positive experience and that the goals of GeCAA were achieved. For example, to the question "Please rate your overall experience participating in GeCAA" on a scale from 1 to 5 spanning "poor" to "great", 98% of survey participants gave a ranking greater than or equal to 3, and for the question "Please rate how strongly you feel GeCAA made a positive impact on your view of astronomy and astrophysics", 94% of respondents gave a ranking greater than or equal to 3, with 43% choosing the maximum ranking of 5. Qualitatively, the students described the GeCAA experience with phrases such as "feeling like a scientist", "solving fun challenges", "having an overall fun and rewarding experience". Aside from the theoretical experience, competitions also give students the chance to explore the observational and practical part of astronomy. Students often get the chance to engage with telescopes and learn to observe the sky with them.

A very important aspect of the competitions is that they help build community. Through the training and participation process, students often develop many friendships, many of which last into the next stages of their life, and create their support network and community in their academic journey. In students' feedback, they said they appreciated "learning from each other", and "learning the value of teamwork".

Most importantly, the competitions at the international level bring together many countries, such as IOAA who receives participants from 46 countries, and IPhO who gets 85. This helps the students become accustomed to and develop international collaborations, which are very important for many of their future careers.

Finally, competitions play a role in research retention in the long term, and serve as a pipeline for a career in research. Competitions expose students to research questions, and get them thinking about challenges they would like to pursue in science. Problems are created straight from research applications (ex: gravitational wave detection, using transit timing variations and transit duration variations to detect exo-moons).

Competitions provide networks necessary to educate students early on on the path to research, and they create a community of researchers and mentors who are available to offer support to the students. Many alumni of the astronomy and astrophysics olympiad programs have pursued studies of math, physics and astrophysics in college, and have even pursued PhDs and beyond.

In conclusion, through the training and participation program, competitions bring an important impact on education, where they increase awareness of astronomy and astrophysics, directly educate student in the field, and provide opportunities for observational practice; they contribute to community building, encouraging friendship, communication, and international collaboration; finally, they play a role in research retention, by creating a pipeline for a career in research.

Project-Based Competitions

Speaker: Danijela Takač, Croatian Astronomical Society, Croatia

This talk will address the national astronomy competitions in Croatia from a teacher/mentor/committee member point of view. In a more than 50 years tradition of competition in astronomy there have been different models of realization. There were years only with the theoretical round, only with the project round and with their combination (nowadays). It will be shown the benefits and problems we encounter when applying each model as well as the problems of objective evaluation of project-based competitions.

Talk link: https://youtu.be/J_32mIym75Q

Astronomy competitions have been organized in Croatia since 1967. From the beginning until 2008, the competitions were organized and realised by a several non-government organizations and societies (Narodna tehnika, Astronomical Astronautical Society "Zagreb", Croatian Natural Science Society (HPD), Croatian Astronomical Society (HAD)) with support of Zagreb Astronomical Observatory, local astronomical societies, schools and Ministries.After 2008 the organization was given to AZOO (Education and Teacher Training Agency) that is still responsible for it.

The Astronomy competition consists of 3 rounds: school, county and national. At the beginning of competition (usually during December and first half of January), students must send abstracts of their projects. They are reviewed, approved (or rejected) and suggestions are sent back to them. The school round is organized by the teachers in their own schools and is a way of selecting the best students that later attend the regional competition. School round is usually held in January and consists only of a written exam. Students from 5th to 12th grade compete in 8 classes. The second round is the county competition and it is organized in March within schools in each county separately. This round consists of a theoretical exam and students are obliged to bring their project report. Every project can be realized by two students from the same class. The national committee then anonymously reviews the projects (by two referees in each class). The students with the best combined exam and project results are invited to the national round in May.

The members of the national committee have designed a grading rubric for the projects. The committee members grade the clear goals and logics of the project work, motivation, grammar and spelling, detailed and clear description of the used materials, equipment and the work reproducibility. They also grade the quality of the result analysis, calculations of the errors as well as the quality of the conclusion. In the rubric there are points for naming all the references and sources of photographs used. The last grading point and one of the most difficult ones is the innovation and amount of work put into this project. The committee also writes their remarks on the project work as well as suggestions for improvement.

Upon attending the national competition students write the theoretical exam and afterwards present their project using the Powerpoint presentation. There is also a rubric to help the committee with grading the presentations and posters. This rubric evaluates the clearness and order of the presentation, how the student is familiar with the theme of his project, the presentational skills, the design of the presentation as well as the quality of the suggested improvements the students made. Final ranking list is made based on the exam, presentation/poster results and project review. The winners and runners up are invited to attend the selection for the national IOAA team, organized by the Zagreb Astronomical Observatory and Croatian Astronomical Society.

During the years we have tried different approaches to organizing astronomy competitions. When I first started teaching astronomy, 4th grade students (10-year-olds) could also compete on the regional level but only with the written exam. As a teacher I found it very motivating for the students because they could get the overview of the competition before attending it in the 5th grade. In middle school, astronomy is an extracurricular activity and teachers usually have it once a week, but it is mostly not enough if students want to participate in the competition. Teachers have to prepare students not only for the written exam but also mentor them during the making of the project. High school students are easier to mentor since they are more independent as the 5th and 6th grade students have to be mentored step-by-step. The biggest problem usually is the math background (statistics) and their minimum knowledge of the scientific method. Sometimes teachers have to be very creative when choosing the topic of the project and making it more simple for the young students. They also have to keep in mind that any project you are competing with should have measurements, calculations and analysis of the results and calculations of the errors. This is easier to do in the last two grades of middle school as the students have physics and chemistry as subjects and understand the scientific process. Nevertheless the project part of the competition is the most demanding and the most rewarding. Students have to work extra hard for a month or two depending on the topic and they learn so much more than during regular lessons. In fact, the astronomy competition is one of the most demanding STEM competitions in the Croatian educational system. For example, the national physics competition has two categories: theoretical (exam) and project-based one, but in astronomy they are combined in one.

As a teacher/mentor I usually choose the students that will attend the competition very early in the school year and start working with them on their project long before January. I usually help the youngest students decide on a topic and design a project that could be measured in the daylight or for just a few nights of stargazing since one cannot expect 10-year-old students to spend nights outside measuring in the cold.

Teachers try to motivate students by integrating astronomy projects in the physics or technology curriculum, explaining to them that by doing these projects they would "become scientists" and get an idea of the exciting work real astronomers do every day. After the students pick their project topic they explore it online, make a plan on the experimental measurements and prepare stargazing charts. After gathering the measurements students analyse them and write a report (10 - 15 pages). Before the national competition students design a Powerpoint presentation and a scientific poster. I love the idea of a poster because it gives a "real scientific conference vibe" and the students can browse the posters the committee hangs in the halls of the venue and brainstorm the ideas for topics they can do for the next year’s competition.

During the years the national committee has tried different approaches to the competition. National competition consists of only exams, but as it is only theoretical knowledge and in astronomy observing the sky is a "must" and a biggest motivation for students and future young scientists so it was not very well accepted. The committee also tried to hold the national level of the competition with students only presenting their projects but the students felt it was unfair and subjective because some national board members liked some topics more than others, so it was decided to hold both theoretical and practical parts of the competition. This is not a perfect system but for now it works well. There are some margin for errors as well as room for improvements. For example, the biggest problem we are facing is the lack of students that are willing to compete. There are many factors that contributed to that through the years, like the fact that the Ministry of Education does not allow astronomy to be a optional subject, but only an extracurricular activity which brings problems to teachers as they are often not supported for that and students do not get grades so they are sometimes not motivated in taking part of it. Also we have found that mostly physics and geography teachers feel confident enough to teach astronomy and prepare the projects for the competitions.

Anyhow, experienced teachers, with the help of astronomers, organize teacher trainings as well as workshops for young children and students in order to increase their interest in Astronomy and STEM as well as teach them scientific literacy.

Astronomy Education: Unlocking Creativity in Kids through Astro Art Competition

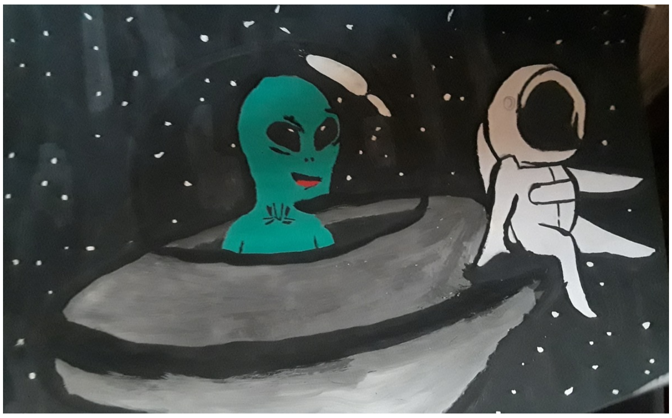
Speaker: Olayinka Fagbemiro, Astronomers Without Borders (AWB), Nigeria

An excellent medium of teaching astronomy to kids, especially from less privileged background is through Arts which provides an avenue to express their creativity. The Covid-19 pandemic which resulted in a prolonged lockdown on schools across Nigeria was utilised by AWB Nigeria to launch the first ever Astro Art Contest in the country. This maiden Edition of the Astro Art Contest for Elementary and High School kids in Nigeria saw 164 entries sent in by participants from across Nigeria. The star prize in this contest being a SSVI homemade telescope signed by foremost Belgian Astronaut, Dirk Frimout was a great motivation for participants. For entries submission, participants were expected to make paintings on an A4 sized paper accompanied with a short write up describing their art work.

Talk link: https://youtu.be/gNTh0rwq55c

An excellent medium of teaching astronomy to kids, especially from less privileged backgrounds is through Arts, which provides an avenue to express their creativity. AWB Nigeria launched the first ever Astro Art Contest in the country. This maiden Edition of the Astro Art Contest involved Elementary and High school kids aged 8 - 18 years. The participants were required to send in their entries, Astro Art paintings on an A4 sized paper accompanied with a short write up describing their artwork. In all, 164 entries were sent in by participants from across Nigeria. There are a number of lessons we got from the competition. Kids have interesting ideas about Astronomy. The participants came up with really great ideas about their understanding of Astronomy. Their paintings showed they understood the concept of Astronomy reasonably well.

Art brings out the creativity in kids. With arts, the imagination of these kids is unlocked and they begin to showcase great talents. Kids ask the most intriguing questions about space. They want to explore the many possibilities that lie within and outside of our cosmos. Creative Art presents a great avenue to teach Astronomy to kids without having to worry so much about the technicalities and big terms they may not fully understand. Having an Astronomy competition that is art-based created the opportunity to explore different aspects of Astronomy in a country where Astronomy is not taught at the Elementary and High school levels. The winners of the Astro Art competition were rewarded appropriately and there were a lot of consolation prizes as well. This was done to motivate the kids and encourage them to do better in subsequent editions of the competition which we believe has come to stay.



The Educational and Scientific Importance of the CanSat School Project

Presenter: João Dias, ESERO / Ciência Viva, Portugal

CanSat Portugal is an educational project of ESERO Portugal, organised by Ciência Viva and ESA. This initiative challenges secondary school students from all over the country to design and build a functional model of a small satellite with the same dimensions as a soda can. All teams are given a primary mission and have to choose a secondary one. They have to design and build their own CanSat, along with its parachute, prepare it for launch, assure its communications with the ground station and analyse the scientific data obtained. They are also strongly advised to look for external scientific and technological support. Overall, this competition engages the students to work together as a team on a real space mission and to live a challenging yet fun scientific and technological experience.

Poster link: https://youtu.be/rh0YmNEXm94

CanSat Portugal (https://www.esero.pt/568/8---edi--o-do-CanSat-Portugal) is an educational project of ESERO Portugal and Ciência Viva's National Agency for Scientific and Technological Culture. This competition has an international version run by ESA Education for the winners from each country.

This initiative challenges teams composed of 4 to 6 secondary school students from all over the country to design and build a functional model of a micro-satellite with the same dimensions as a soda can – hence the name CanSat. This competition gives students the opportunity to go through all the stages of a real space project throughout a whole school year. Each team's work is mentored by one teacher from their schools. The mentors do not need to be science teachers. The process required to develop a CanSat implies a learning process known as *problem-based learning*, a teaching method in which the students are the main characters and must be the ones who solve the problems. In Portugal, the students' work is evaluated in the competition's final by a jury composed of experts in Space education, science and technology. Essentially, they are all researchers and/or engineers working in space-related companies and scientific institutions.

All teams have the same mandatory primary mission to achieve, which allows the jury to compare the work developed by each team, their results and the methods they use to reach a common goal. In particular, it consists in measuring the atmospheric temperature and pressure. Each team also has to choose a secondary mission of their own, offering the students the opportunity to make use of their creativity and knowledge to achieve an original scientific goal. In general, all teams have to design their own CanSat, integrate all its components, test its systems, build its parachute, prepare it for launch and analyse the scientific data obtained. The students are also responsible for the satellite's communications with its ground station. In other words, this school project invites the students to make good use of what they learn in the school curricula and tests their skills to work together as a team on a challenging and innovative Space project involving so many theoretical and hands-on activities with a high level of difficulty.

The students are also invited to promote their work in their educational community and on social media and are highly advised to look for external scientific and technological support, such as partnerships and consultancy. In addition to technological and scientific competences, students develop other skills such as teamwork, communication in Portuguese and English and problem solving. The winners of each edition have the opportunity to represent Portugal in the European CanSat Final, which takes place every year. Overall, this competition engages the students to work on a real and large-scale Space mission and to live a demanding yet fun scientific and technological experience.

On a final note, it is very rewarding for us, as organisers of this competition, to see the great impact it has had over the years on the student's lives, their higher education performances and even on their future careers. Just to give an example, many of them got university scholarships for participating in CanSat or were offered internships in the industry or science research centres. But most of all, it is textbfvery rewarding for the students to reach the final of such a demanding competition after a whole school year of hard work, fulfilling their dream to see the micro-satellite they built being launched from a rocket, falling down safely with the help of the parachute they built, to collect their signals with an antenna they built and to analyse the results of the mission they choose, reaching a scientific goal together as a team. I am sure they will all remember and cherish this experience for the rest of their lives!

Innovation in Space Science Learning Project

Presenter: Madelaine Rojas, National Secretariat of Science, Technology and Innovation (SENACYT), Panama

The free professional development programs and astronomical contests inspire, engage and empower the next generation of Panamenian scientists. The number of registered in all the activities presented a decrease in the pandemic. Therefore, the objective of the study is to correlate audience participation to astronomy outreach activities. For this study we have maintained an updated participants database that allows a qualitative, quantitative, and documentary analysis. The database is categorized by regions, gender and interests. Audience participation rates differ by gender with 60% female participation in astronomical competitions and 90% female participation in professional development programs.

Our intention with the Space Science Learning Project is to inspire the general public, the next generation of space enthusiasts and the educational community with tools and experiences that allow them to get an idea of what it means to be an astronomer, to work in science, and to discover the mysteries of the Universe. The project´s mission is to promote and safeguard astronomy in all its aspects, including research, communication, education and development, through international cooperation.

Throughout the pandemic, free professional development programs and astronomical contests have remained active to inspire, engage and empower the next generation of Panamanian scientists. In our country we have different activities to promote astronomy popularization and education. However, even though the number of registered participants in all the activities that we have carried out have been acceptable, we have presented a noticeable decrease in the number of people who remained participating continuously.

Therefore, the objective of the study is to correlate audience participation to astronomy outreach activities. For this study, we have maintained an updated participants database that allows a qualitative, quantitative, and documentative analysis.

The database is categorized by regions, gender and interests. Audience participation rates differ by gender with 60% female participation in astronomical competitions and 90% female participation in professional development programs. It will be presented how the analysis to develop an astronomy education kit aimed for teachers and how this cooperation between an academic institution and schools is helping educators in their pedagogical practice to teach astronomy in the classroom.

Every year, students and teachers from all over the country take part in the Panamanian Space Sciences Olympiad (OliPaCE). This has the aim of both spreading space science concepts and training teachers about these topics. A valuable link with the community at the national level will be generated by involving the entire educational sector in Panama, including children with special needs.

Also, we educate new generations of teachers and re-educate the current ones. We work with university professors and amateur astronomers in order to train future teachers and we cooperate with the departments of education in order to train experienced elementary and high school teachers.

The Innovation in Space Science Learning Project has a Network for outreach coordinator that visits a marginal community to help tackle educational disparities and improve access to STEM for women and girls in astronomy. The main goal is to set up in each country a local group of outreach members who carry on teaching space science every year and create new courses by using our materials, like animations, articles, photos, games, simulations, interactive programs and videos.

Qatar Astronomy Olympiad for Schools

Presenter: Hani Dalee, Olympiad Coordinator and IAU-NOC, Qatar

In our poster, we are going present a summary of "Qatar Astronomy Olympiad for Schools" and its different projects, which were carried out in different editions of the Olympiad. We will show the positive impact, as students were involved in the work. We will also show how we could utilize these events to create a community of amateur astronomer descending from different nationalities who are living in the State of Qatar.

Poster link: https://youtu.be/kFPgEJIkYFY

Qatar Astronomy Olympiad for Schools is an annual competition started at HBKU university in 2015-2016, in cooperation with QNRF and the Ministry of Education.

The competition is dedicated for the students in both middle and high schools. It covers topics about astronomy, astrophysics, astrophotography, space physics and other applicable topics.

So far, six Olympiads were organized with 17 astronomical projects carried out by students.

The average number of students participating in the Olympiad every year is 300 students from local and international schools. Each school was asked to form a team of 4-6 students to carry out the assigned projects, one or two teachers were allowed to supervise this team, with 60 is the average number of schools participating in the Olympiad each year.

Projects of the Olympiad: Each competition was fulfilling particular objectives, depending on the level of students targeted; middle or high school students.

1st Olympiad - 2015/2016 - 35 schools from 160 Students. The projects are: Eratosthenes Measures the Circumference of the Earth, How the Big Dipper will look like after 100,000 years from now, Hands-on for the Real Model of the Solar system and Assemble your Galilean Telescope.

2nd Olympiad – 2016/2017 - 344 students from 59 schools. The projects are: Make a Sundial for Your School and Make an Astrolabe and Use It.

3rd Olympiad - 2017/2018 - 420 students from 84 schools. The projects are: Al-Biruni measures the Radius of the Earth, Make a Star Dome and The Qatari Calendar: Study & Analysis.

4th Qatar National Astronomy Olympiad for Schools – 2018/2019 - with 340 students from

65 schools. The projects are: The Physics of the Winter Hexagon Stars, make a Model for the Stars of the Winter Hexagon and Draw the constellations of the Winter Hexagon.

5th Olympiad – 2019/2020 - 220 students from 56 schools. The projects are: Mercury Transit- 11 November 2019, Annular Solar Eclipse- 26 December 2019 and Voyager's Pale Blue Dot- 30th Anniversary 14 Feb 2020.

6th Olympiad – 2020/2021 - 246 students from 57 schools. The projects are: Measure the Distance to the Moon by Parallax and Lunar & Solar Mansions.

Benefits and output of the Olympiad: Enthusiasm among students was seen through their manner of talking and explaining. A group called Amateur Astronomy in Qatar was founded and the Qatar team for the International Olympiad on Astronomy & Astrophysics was formed.

Discussion summary

The talks were followed by a lively discussion with the speakers. Audience members were interested in knowing more details about project-based competitions that are integrated in Croatian Astronomy Olympiad program. There were queries how students found the whole experience and how much support such a concept gets from school teachers. One of the colleagues of Danijela Takač joined the discussion and explained that the teachers mentoring the Olympiad participants realise value of such proto-research projects and hence are very enthusiastic in helping their students. There were also questions about prestige associated with Astronomy Olympiads vis-a-vis Physics or Mathematics Olympiad and if Astronomy Olympiad like competitions can be introduced for slightly younger students (roughly aged 14-15). The speakers explained that the Astronomy Olympiad is much younger than Physics or Mathematics Olympiad, hence it would be unreasonable to expect similar levels of participation immediately. Speakers also discussed the need to have an ecosystem of student competitions where all competitions learn from each other and work towards the common goal of attracting school students to astronomy.

Teaching about Indigenous Astronomy

Session organiser: Sivuyile Manxoyi, South African Astronomical Observatory, South Africa

Session overview

Astronomy is the most ancient discipline of science and one of its unique features is its multicultural roots. This stems from the fact that every person in the world has a profound relationship with the sky and the stars. This session explored the relationship between astronomy, culture and society; appraised the value, relevance and significance of indigenous astronomy. This predates western academic astronomy by thousands of years. This session concludes by revisiting challenges experienced in the teaching of indigenous astronomy and appropriate pedagogical approaches were shared.

Some of the challenges noted are the absence of indigenous astronomy content in school curricula in many countries, inaccurate representation, constant description of this knowledge and practices as irrational and absence of training and support for teachers. Reflexivity, recognition of epistemological diversity and willingness to engage in intercultural dialogues are imperative for the successful teaching of indigenous knowledge.

Appreciating multiple facets of different astronomies allows us to better understand how human ideas and models of the sky are generated. The teaching of indigenous astronomy presents us with an excellent opportunity to rehumanize science and society.

Astronomies, Cultures and Education

Speaker: Alejandro Martín López, CONICET, Sección Etnología, Instituto de Ciencias Antropológicas, Universidad de Buenos Aires, Argentina

Some people talk about "astronomy" (the academic Western one) and "cultural astronomies" (the astronomies of "particular" cultures). This is a profound misunderstanding of the legacy of three decades of cultural astronomy studies. In this presentation we aim to discuss this confusion and to point out the contributions of cultural astronomy studies in thinking about astronomical education from an intercultural perspective. The sky and their phenomena have been an area of great interest for many cultures throughout the planet over time. In "Western culture", since the Copernican revolution, astronomy has become a model for all science. Due to the colonial expansion of the Western society their academic astronomy is taught today in the most diverse places on Earth. However, cultural astronomy has shown us that every astronomy is the result of a history and a society. "Western academic astronomy" is not "the" astronomy, and it is grounded – like all the others – on a series of implicit cultural assumptions. A truly inclusive and decolonial scientific education for our present and future world, supposes the possibility for the students and teachers of a critical appropriation of "Western academic astronomy", and the chance of putting it in dialogue with the astronomical knowledge systems of their own societies.

Talk link: https://youtu.be/qn8a_mzAeCM

Some people talk about "astronomy" (the academic Western one) and "cultural astronomies" (the astronomies of "particular" cultures). This is a profound misunderstanding of the legacy of three decades of studies in cultural astronomy. Cultural astronomy is an interdisciplinary academic field, not an adjective to identify some kind of "strange" astronomy.

Cultural astronomy is the study of all astronomical systems as social facts; not a search for fragments of "our" astronomy in distant cultures. This interdisciplinary field includes as some of their sub-fields: ethnoastronomy, archaeoastronomy, and a social history of Astronomy. In this presentation we aim to point out the contributions of cultural astronomy, especially ethno astronomy, in thinking of astronomical education from an intercultural perspective, transforming it from the point of view of cultural astronomy.

Ethnoastronomy is a perspective, a way of approaching ethnographically, ethnologically and anthropologically the knowledge and practices about the sky of any contemporary social unit (such as an ethnic group, a social class, a family, a professional group, or an institution; both "Western" as "non-Western"), understanding them as an integral part of their social and cultural life. It seeks to place that knowledge and practices in their regional and global context, as well as in their historical development. It is interested in generally shared and largely implicit knowledges and practices (logics of practice, lebenswelt, worldviews/cosmovisions) and also, those more explicitly formulated and frequently associated with specialists (cosmologies, ontologies); understanding all of them as articulated, but always unfinished and under construction. Among the notes that characterize the ethno astronomical view, we can mention: a) the interest focused on giving an account of the perspective of the group studied; b) the question about the meaning of practices, discourses and their complex links; c) the holistic intention (any aspect of social life must be seen in connection with the whole); d) the centrality of the direct presence of the researcher and his / her interpersonal links with the members of the group studied; e) the "estrangement", as an effort to denature one's own common sense and that of the group studied; f) "reflexivity" or conscious analysis about our own position and influence in the construction of knowledge; g) a dominantly inductive character that includes comparison, models and general theories; h) the application of many combined techniques (such as interviews – especially informal – archives, life stories, elicitations, network analysis, images, videos, audios, surveys, statistical data, etc.) but articulated with participant observation; i) commitment, involvement and reciprocity with the studied community and local circumstances.

From ethnoastronomy we can learn that astronomical knowledge – as all human knowledge – is a socio-cultural construction, an important part of our adaptation to the world we inhabit: a physical, biological, but also social environment. Our world is a universe full of meanings, schemes of perception and metaphors in which we are introduced by other members of our society, essentially by primary socialization, imitation, and day-to-day life. The experience of the senses limits the possibilities of any human world view, but not to the point of generating a single compatible option. Also the social character of this knowledge and the need to legitimize that knowledge and comply with accepted truth regimes imposes limits on the possible world views in a given society at a given time, but they are not absolute either and they do not unequivocally determine only one possibility. From these socially shared ideas, or world views, grows the explicit systems of knowledge about the world that we call cosmologies. World views and cosmologies are poles of a continuum. Every system of ideas and practices about the sky has a constitutively unfinished and changing character, and is connected to general ideas about body, person, space, time, causality, etc. Also, knowledge systems are always involved in the general social field, with varying degrees of autonomy with respect to it and this implies that they are strongly traversed by power and social institutions.

The sky and their phenomena have been an area of great interest for many cultures throughout the planet over time. In "Western culture", since the Copernican revolution, astronomy has become a model for all science. Due to the colonial expansion of the Western society, their academic astronomy is taught today in the most diverse places on Earth. However, cultural astronomy has shown us that every astronomy is the result of a history and a society. "Western academic astronomy" is not "the" astronomy, and it is grounded – like all the others – on a series of implicit cultural assumptions. A truly inclusive and decolonized scientific education for our present and future world, supposes the possibility for the students and teachers of a critical appropriation of "Western academic astronomy", and the chance of putting it in dialogue with the astronomical knowledge systems of their own societies.

Cultural astronomy has an enormous potential to collaborate in a radical improvement of astronomical education. A deeper understanding of the astronomies of other cultures, which does not relegate diversity to a distant past, would be crucial to improve the teaching of astronomy in the world. But a huge amount of material about the astronomy of different cultures used in the teaching and popularization of astronomy, has no methodological rigor. Also, astronomies of other cultures are usually used in an "anecdotal" manner, as a kind of curious introduction to the strange things that were "thought" before the arrival of Western science. Hopefully, there are professionals in cultural astronomy and professional associations: Sociedad Interamericana de Astronomía en la Cultura (SIAC), Société Européenne pour l'Astronomie Dans la Culture (SEAC), International Society for Archaeoastronomy and Astronomy in Culture (ISAAC). They can help us to address the different ways of knowing the sky in greater depth, understanding its structure, allowing us to appreciate the way in which the ideas and models with which humans seek to know the world are generated. Also, they can help us to understand the logics, metaphors, interests and observations in which the Western Academic Astronomy rests, making it easier for educators to design strategies to approach the teaching of this kind of astronomy in diverse cultural contexts, and for the people to critically appropriate of Western Academic Astronomy. Also, we can learn a much wider variety of models, metaphors and approaches to the sky that can also be useful for Western Academic Astronomy.

Central and Mesoamerican skies: More than 4000 years of Astronomy

Speaker: Javier Mejuto, Archaeoastronomy and Cultural Astronomy Department, Space Sciences Faculty, National Autonomous University of Honduras (UNAH), Honduras

The archaeological record of the Meso and Central American peoples allows us to recognize, without a doubt, a methodical and continuous knowledge of the celestial space. Beyond this, indigenous peoples have perpetuated and are custodians of that knowledge in its most varied cultural expressions. This valuable astronomical knowledge brought to the classroom not only allows us to expand our knowledge of the universe and the human being, but also allows us to educate in a transversal way using ancestral astronomical knowledge to deconstruct ethnocentric discourses that support epistemological hegemonies, bringing the student closer to an explanation of the complex reality of our world.

Talk link: https://youtu.be/qYmm87cOUHY

The archaeological record of the Meso and Central American peoples allows us to recognize, without a doubt, a methodical and continuous knowledge of celestial space. The first thing that we must take into consideration is that astronomical knowledge in other cultural contexts includes not only celestial space but also agriculture, weather forecasting, worldview, among others. That is, we must bear in mind that it is a knowledge system and not isolated knowledge.

In the Mesoamerican cultural context we can identify three types of structures for observing the sky, either directly or indirectly. The first type is the hemispherical, similar to the observatories of contemporary western astronomy. An example we have in the Caracol of Chichén Itzá, Mexico, from which specific moments in the apparent movement of Venus were observed. The second type is the horizontal observatory where the shadows of vertical elements, such as stelae, are used to know the time of year along with other ritual aspects. An example of this can be found in the Plaza de las Estelas de Copán Ruinas, in Honduras. Finally, the vertical observatories, used to know the days when the sun passes through the zenith (Aveni, 1981). Astronomical events typical of the intertropical zone and that in the case of the first passage of the sun through the zenith coincides with the beginning of the rainy season with the obvious agricultural implications for Mesoamerican communities. Examples of this type of observatories are in Xochicalco and the P structure in Monte Albán, both in Mexico.

We can also identify, through iconography, which celestial objects were mainly observed. The personification of the solar god K'inich Ajaw appears profusely in a variety of archaeological sites but perhaps the most profuse is in Kohunlich with its stuccoed masks (Velasquéz, 1995) or the Mayapán paintings located in the same country. This god also appears in the company of the moon goddess on the celestial bench of the Honduran site of Copán Ruinas. As we might expect, both the sun and the moon are the most represented celestial bodies but not the only ones, among them, the next in frequency of appearance in the archaeological record is the anthropomorphization of Venus. Although there are also many records on various supports, the paintings and representations in Cacaxtla are of relevance throughout the cultural area. Assumed as an omen of misfortune whose light was pernicious, it was related to the Haab civil calendar of 365 days through its synodic cycle and to the eclipses, well known in Mesoamerica. Of this we have written sources such as the so-called eclipse table of the Dresden Codex or the solar eclipse of 1531 that appears in the colonial section of the Telleriano-Remensis Codex (Códice Telleriano-Remensis, 1964).

Although it is only a brief brushstroke of the enormous knowledge of the celestial space that was developed in the Mesoamerican cultural region, we cannot ignore that it is not a petrified and forgotten knowledge but that it is still alive through the indigenous peoples that currently inhabit the region. This valuable astronomical knowledge brought to the classroom not only allows us to expand our knowledge of the universe and the human being, but also allows us to educate in a transversal way using ancestral astronomical knowledge to deconstruct ethnocentric discourses that support epistemological hegemonies, bringing the student closer to an explanation of the complex reality of our world.

Despite all this clear astronomical knowledge accumulated for more than 4000 years, we do not see it at all reflected in the curricula of the history of Astronomy subjects or in the associated degrees (as it happens with other cultural regions worldwide). This gives an idea of an unique course in the history of celestial space knowledge together with an evolutionary idea of it. Nothing could be further from reality. Astronomy, as a science, is a cultural product that has meaning and validity within the culture that has developed it, as is the case in past and contemporary cultures. With this we must motivate students to appreciate epistemological diversity both in the past and in the present and its value for the present and the future of humankind. Expanding our understanding of other knowledge systems is not only important from an academic and pedagogical point of view, but it is an education in values that makes us stop looking only upwards, without a cultural or social context, to dream a future for all among the stars.

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Astronomy Education at the Crossroads of Science and Indigenous Knowledge

Speaker: Duane Hamacher, School of Physics, University of Melbourne, Australia

The Knowledge Systems and cultural traditions of First Peoples around the globe contain layers of complex scientific knowledge derived from detailed observation, experimentation, collected wisdom and deduction through a priori and a posteriori systems of knowledge, which is passed down to successive generations through oral tradition. By learning from the teachings of Indigenous Elders, we can understand a great deal about the development of scientific information and how that can be used for a variety of applications. As Elders teach, everything in the sky is reflected on the land, a concept promoted by Annette Lee in the Lakota First Nation as Kapemni. As science educators, we also need to consider ways of assisting First Peoples who can approach scientific research and education through the lens of Etuaptmumk, "Two Eyed Seeing" - what Mi'kmaw elder Albert Marshall explains is seeing with one eye through the Indigenous world and the other through the Western academic world. This occurs at what Torres Strait Islander educationalist Martin Nakata calls the Cultural Interface. These theoretical frameworks provide a foundation for teaching Indigneous astronomy and science, and support the next generation of Indigneous scientists. This talk will focus on these frameworks and show examples from around the world about how Indigenous cultures developed scientific knowledge about the machinations of the cosmos and their relationships to events on the Earth.

Talk link: https://youtu.be/bsvEmuQorA0

Teaching Material of History of Astronomy Using Digital Archives in Japan

Speaker: Harufumi Tamazawa, Kyoto University, Kyoto City University of Arts, Tokyo, Japan

Digital archives make us learn the history of astronomy more effectively. Understanding the transition of the view of the universe is important in learning astronomy, but there are few teaching materials or workshops prepared compared to those who learn knowledge of astronomy. It is useful to touch on historical documents about astronomy. The promotion of digital archives in recent years provides this opportunity. In a class on the history of astronomy at the university, using digital archives, students searched for a diagram of the solar system drawn in historical documents about astronomy in Japan and conducted a task to consider how it differs from the real solar system. Using digital archives may make students understand how the heliocentric theory has flowed into Japan and the transition of the view of the universe deeper than simple lecture.

Talk link: `https://youtu.be/7EvkJ4pP8wc`

When considering the relationship between education and history in astronomy, it is necessary to consider how to incorporate historical content as a teaching material in astronomy. In the case of archaeoastronomy, site, heritage, land/skyscape are research contents. In the ethno astronomical approach, records and memos of habits, narratives, movements such as songs and dances are research material. What does it take to convert these research content into educational content? Archive is useful to change research material to educational material.

NOJIRI Hoei（野尻抱影）(1885-1977) and KITAO Koichi（北尾浩一）(1953-) are pioneers of folklore studies of astronomy in Japan. They have asked people and collected star names in each region. Kitao has collected not only words but also folk songs about astronomy in Japan (for example , Kitao 2021). In some cases, however, the interview survey was not conducted on the premise that the archive will be released, so some material about research is not able to be used. In the field of paleoastronomy research, researchers use document archives to search for useful documents to detect astronomical events in history. For example, in Hayakawa et al. 2017, archive of Japanese historical documents in order to know how large the space weather event in 1770 was. There are two types of approaches to change research material to educational material about indigenous astronomy. In the case of Ethnoastronomy or Folklore studies of Astronomy, archiving of research material (recording data, memo, and so on) itself is education. On the contrary, in the case of the history of astronomy or paleoastronomy, archiving research material and using archives is also education.

How about the relation between archive and lecture? History of astronomy is usually taught in "classroom type lectures". What are the teaching materials of the history of astronomy? After Covid 19 pandemic, lectures in university were changed to online, therefore lecturers should make online versions of teaching materials of the history of astronomy . What is the teaching material about the history of astronomy, especially the transition of the view of the universe? Examining papers on astronomy materials that include historical content reveals that they can be divided into three types; Reproduction of historical observation methods (including calculations), remake (creation of past observation instruments), and reuse (observation and consideration by visiting and using the real thing (Astronomical heritage, old telescope). To make material about the transition of the view of the universe, however, we should make another type because we should approach cultural Astronomy and Input science Studies, philosophy of science.

The author conducted the following tasks in a class on the history of astronomy as a test case. Students search "平天儀図解"（Heitengi-zukai） written by Zenbei Iwahashi (telescope craft worker with lens), using "Japan search", portarsite about japanese archives, and look at the figure, point out the points that are different from the current way of thinking of the solar system, and ask them to think about what causes them. Many students do not explain that it is a simple geocentric diagram, but they explain that the moon, the sun, Mars, Jupiter, and Saturn are rotating around the earth, and Venus and Mercury are rotating around the sun. About 10% of the students made comparisons with Tycho Brahe and others. There was a tendency for the amount of description to be larger than other lesson contents. It is presumed that many students were interested in the task.

To make teaching material of indigeneous astronomy, an archive of research material is important. Researchers should make a methodology of archiving research material of ethnoastronomy or folklore studies of astronomy(rule, ethics, privacy, skill, and so on). Using of archiving, and related studies (History of science, Science studies, and so on) is also important to make teaching material about ingigeneous astronomy.

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Discussion summary

The questions and discussion focused on the availability of material for teaching indigenous astronomy and readiness and preparedness of teachers to teach indigenous astronomy. So far, there is a growing movement of developing materials in the USA, Canada, Australia, and South Africa. However, the development and circulation of best practices in materials development for indigenous knowledge are needed as well as collaborations across the countries and continents.

Furthermore, some universities have begun including indigenous knowledge teaching in their education and science education courses and training programs. There are organisations dedicated to development and support of indigenous astronomy such ISAAC (International Society for Archeoastronomy and Astronomy in Culture) and host conferences annually.

All the speakers, without exception, emphasized that all knowledge is socially constructed including astronomical knowledge. Therefore, astronomy has to be viewed as a cultural product, even though every culture has its own version of astronomical knowledge. Western academic astronomy is one of the many versions of astronomical knowledge. Its dominance can be ascribed to colonial past and current western cultural imperialism. It is critical and imperative to acknowledge, recognize and respect astronomical knowledge of other cultures, Indigenous cultures in particular.

There were questions and an elaboration by Martin Alejandro Lopez on intercultural approach to the teaching of astronomy. He pointed out that it is empowering for learners to learn about how other astronomers of other cultures handle and understand the sky and the stars. Recognizing that cultures influence each other and have many commonalities may assist in addressing issues of domination, disrespect and powers. He argued that recognition of indigenous practices may assist and contribute to the decolonization of knowledge and science.

Teaching Methods

Session organiser: Sara Ricciardi,
INAF OAS/Game Science Research Center,
OAE Center Italy, Italy

Session overview

This workshop session is devoted to analyzing teaching methods and practices that can encourage students' engagement and the understanding of Astronomy, Astrophysics and in general STEM disciplines and their methods. For this round of the workshop we decided to focus on primary and junior secondary school levels but we believe our conversations are relevant in general and for learners of any age.

So the first questions we posed preparing this session are: in the school environment how should STEM learning be? How can Astronomy be integrated into that?

We found a common ground in the vast majority of the talks and posters submitted. Some people clearly pointed out that the learning experience should be meaningful and significant, learners should be able to experiment and understand with their own experience. Others suggest the learning should be personal and creative as personal and creative is the work of scientists. Others focus more on a very important aspect that regards the idea of STEM learning and how this is connected with children's lives and worldviews. STEM learning should be for all: we cannot allow the learners to boycott themselves thinking they "are not enough" for science. We also should be conscious that people are different and with different ways to interpret the world; as a community we should provide multiple practices and perspectives. We had 5 speakers from North America (U.S.), South America (Argentina), Asia (Japan), Africa (Tanzania), Europe (The Netherlands) and 5 posters.

A Creative Learning Approach to Astronomy Education

Speaker: Carmelo Presicce, Lifelong Kindergarten Group, MIT Media Lab, USA

In this talk I will briefly describe the 4 P's of creative learning: Projects, Peers, Passion and Play. Despite being quite simple ideas, applying them to the design and facilitation of creative learning experiences is far from easy. The 4 P's do not define a method or a specific practice: they are guiding principles that help educators ask new questions, challenge assumptions, and inform their practice. I will highlight some current experiences in astronomy education that, in my opinion, resonate with this framework. I hope that the four P's of creative learning can be a useful framework for teachers to imagine and develop meaningful learning experiences, helping their students grow as thoughtful and curious inhabitants of the universe.

Talk link: https://youtu.be/1myaeRk1Oto

At the Lifelong Kindergarten research group at MIT we study how to design technologies and experiences to help young people learn by creating. Our group is well-known for creating Scratch, a free visual programming language that allows everyone to easily create interactive stories, animations and video games [1]. But our research is not limited to developing tools. For us it is important that children learn by making projects that they find meaningful, in collaboration with others, and with a playful spirit.

We call this approach creative learning, and we summarize it with four words that we call the 4 P's of creative learning: Projects, Passions, Peers, and Play [2]. The creative-learning approach is applicable in a wide variety of educational contexts and disciplines. In my talk I reflect on how the 4 P's of creative learning can be applied to design-learning experiences related to astronomy.

Projects: People learn better when they are actively engaged in creating something: a sand castle, a poem, a computer program, or a theory of the universe. [3] How can we engage students in an active and creative learning process? What type of projects or activities can help them encounter some particular ideas, or spark certain questions?

In order to see wonderful examples of active and creative learning in astronomy, I suggest looking at the work of Nicoletta Lanciano and Franco Lorenzoni. In their books [4][5] they describe activities in which children make observations and drawings of celestial bodies to track their movements over time; manipulate object or construct physical tools to measure angular distances in the sky; explore myths and traditions from different cultures in the world, and collaboratively write their own myths about the creation of the universe. All these activities allow students to encounter and generate new knowledge through concrete objects and creative experiences.

Passion: When people are engaged in an activity that they find interesting and meaningful, they are more likely to work harder and persist when they face challenges. But although some children might be already fascinated by stars and planets, others might see astronomy as something too far from their life, or simply not for them. How can we design activities that are engaging for everyone?

One way is to make the activities more concrete and closer to their lives. For example, Lorenzoni and other educators organize the "first night of school", bringing students outside to observe stars and planets, sharing stories and questions. It is easy to imagine how exciting it can be for students to meet outside at night, and how this experience can get many of them curious about the sky and what is out there.

Peers: Learning flourishes as a social activity, since people are engaged in sharing ideas, collaborating on projects, and building on each other's work. Learning together can take different forms, from big group discussions to small group collaborations, from sharing feedback to remixing other people's ideas. In such collaborative, peer-to-peer environments, teachers act as facilitators and play a wide variety of roles, sometimes guiding the exploration, other times responding to questions, other times acting as connectors among the students.

I recently participated in an online workshop called "Incontriamo i Cieli del Mondo" organized by Nicoletta Lanciano, Néstor Camino and other astronomy educators, involving participants joining from different continents and latitudes. The workshop fully leveraged the cultural and geographical diversity of participants: we shared myths and traditions linked to astronomical events in our local cultures, we made observations of the Moon from our window at different times, and shared drawings and pictures with others, discussing analogies and differences, and making discoveries that none of us could have done alone.

Play: The most engaging type of learning involves playful exploration and experimentation: trying new things, tinkering with materials, testing boundaries, taking risks, iterating again and again. What type of activities can engage students in an iterative, exploratory, experimental style of learning?

It might seem hard to imagine ways to playfully experiment and iterate quickly with astronomical knowledge, especially when direct observation is involved. But sometimes technology can help. For example, with softwares like Stellarium [6] everyone can simulate the sky from anywhere on Earth at any specific time, make time flow faster or slower, and zoom in on objects as they would with a very powerful telescope. It is definitely not as fun as being outside and watching the sky, but these tools provide unique opportunities to students to experiment and tinker with the sky.

The four P's of creative learning might seem quite simple ideas, but the practice of designing and facilitating creative learning experiences is far from easy. Projects, Passion, Peers, and Play do not define a method or a specific practice: they are guiding principles that help us ask new questions, challenge assumptions, and inform our practice as educators. I hope that the 4 P's of creative learning can be a useful framework for teachers to imagine and develop meaningful learning experiences for their students and help them grow as thoughtful and curious inhabitants of the universe.

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Astronomy Education as a Means to Transform our Worldviews

Speaker: Néstor Camino, Complejo Plaza del Cielo - CONICET-FHCS UNPSJB, Esquel, Chubut, NAEC Argentina, Asociación Argentina de Astronomía, Argentina

The way we see the world is a construction whose characteristics are historical, cultural, social, psychological and strongly associated with teaching and learning processes, mainly through formal education and outreach. We will discuss what elements the actions of Education in Astronomy should have to contribute to the construction of solidarity world views, respectful of diversity and modern in terms of the relationship of human beings with the sky in our time, with projection to a future in peace. and social harmony, linked to the sky.

Talk link: https://youtu.be/tE612QF6Jys

It is possible to define Astronomy, in the broadest possible sense and from the very beginning of human times as one of the cultural forms of civilizations to relate to the sky. In a much more restricted definition, both due to its specificity and its temporality, Astronomy would be a modern activity specialized in building and validating scientific knowledge about the Universe. This last definition is included in many ways in the first one, however, both of them imply that people and human groups build a certain view on ourselves and of the universe that includes us. Furthermore, we can assume that human beings have always built "worldviews" (or also "cosmovisions"), whose main function would be to provide a way to interact and give meaning to natural and social world, whose characteristics are idiosyncratic, historical and cultural, being so broad that they integrate all the aspects that constitute life, individual and social, one of them the sky. In this very complex process, Education, also in the broadest possible sense, is one of the main factors involved in the construction of a certain worldview, both of individuals and of groups.

What can we share in the field of Astronomy among educators from China, Latin America, Africa, Germany, etc.? We do share the key elements of the scientific discipline of Astronomy as a normal science in the present epoch, in kuhnian terms; in other words, we share the constitutive elements of the present paradigm, being built through at least a few centuries. Elements, such as, the ideas of Copernicus, the expansion of the universe, the nature of light, and gravitational waves, observing with the naked-eye or via hyper technological multi-frequency resources, and much more. The dominant paradigm is a strong structure omnipresent, among others, in books, universities, and schools. So, there are not serious differences about those paradigmatic constituents among text books, resources, curricula structures, in those places all around the world. That is because when we teach, what we teach are mainly those paradigm components. We can share, we should share, the fundamental characteristics, theoretical, methodological, even its critics, of the dominant paradigm of what we call Astronomy. But, this is just useful for the Teaching of Astronomy, it is not enough for Astronomy Education.

As scientists, we can affirm that we share a paradigm, in the historical context of our scientific discipline: Astronomy. But people do not live inside paradigms, they (each one of us) live inside worldviews. Sometimes, those worldviews include elements of scientific paradigms: from Astronomy, Biology, Physics, etc.; many other times, they do not. We must remember that it is totally possible to live without a scientific paradigm, even without elements of a scientific paradigm, but it is not possible to live without a worldview.

Astronomers construct paradigms in the small scientific community they belong to and in which they investigate; educators contribute to the construction of worldviews with those who are being educated in a much extended, non-professional and open global community. But worldviews not only are constructed by formal education, which should include elements of those scientific paradigms, they are constructed gradually and continuously from the birth, through other types of education, by religion, family and groups, by social representations, etc., in an even more informal and complex process through the entire vital cycle.

In the broad field of Astronomy Education, we are mainly educators, not just astronomers!!! So, we must consider that Astronomy Education is much more than Teaching of Astronomy, and must be conscious that Astronomy Education is immersed in the whole process of Education, in which the respect for identities, interests and idiosyncrasies must be fundamental, like in the case of worldviews.

It is just the strong idiosyncratic nature of worldviews that must be taken into account when we design any proposal to develop proposals on Astronomy Education, mainly in formal educational systems. When we educate, we do it in aspects of life much more diverse and profound than in a restricted area, whose relevance is no doubt fundamental to our scientific paradigm but that could be irrelevant to everyday life. If we speak of "Astronomy for Education", we must put each of those key elements of the present, complex, and highly specialized astronomical paradigm in a transposition process to create many and diverse educational actions for everyone, not restricted to certain groups of age, gender, capabilities, interests.

It is the Didactics of Astronomy, the most specialized tool that we have to assure that we are really educating through Astronomy, the main goal of Astronomy Education and Astronomy for Education. It is through Didactics of Astronomy that we should accomplished that didactical transposition, to develop myriads of proposals than contribute in a significative way to the construction of worldviews that include the sky among its multiple elements, both in its cultural diversity as from a conception of scientific knowledge.

Didactics of Astronomy means that we take into account the way people learn, more than the way teachers teach; we must think more in terms of learning than teaching, if we want to bring scientific elements to the complex structure of a worldview. Such construction process of scientific elements to be included in worldviews means, among many other aspects, the ability to wonder about what is perceived and to problematize the supposedly validated knowledge, the ability to see differently, to imagine other explanations, different ways to possible futures, actions that will gradually modify the dominant worldviews of the group itself and of the epoch, inside and outside the restricted field of Astronomy as a science.

Furthermore, if we analyse the curricular designs of formal education in our countries, especially at the secondary level, we must ask about the presence and characteristics of Astronomy in them. What paradigmatic elements of nowadays Astronomy are really present in formal education? In which ways are they transposed in order to assure they are being subsumed in a broader, more vivential and significant personal and social worldview, historically and culturally contextualized? Are there actual adequacies of Astronomy concepts and methodologies according to cultural differences? Is there any discussion of Epistemology of Astronomy, in order to comprehend the complex process of scientific knowledge construction, very different to common sense knowledge which is actively present in worldviews? Are there elements of Nature, Science, and Astronomy in those formal curricula? Is there a discussion about social relevance of scientific development and its relationship with, e.g., technology, society, environment, human rights, ethics, life, and what is the role of Astronomy in those items? These are some of the questions we must find answers to, as soon as possible, not only from Astronomy but from Astronomy Education.

It is usual that when planning an educational action, we carry out a diagnosis of previous or alternative ideas, in order to "know the student", as meaningful learning requires. But from the perspective of Astronomy Education as a means to contribute with scientific elements to enrich and diversify personal and social worldviews, that approach is no longer satisfactory. Alternative conceptions are, we must think of them, as the small tip of a huge iceberg. The iceberg is a worldview, but we only perceive and conceptualize the tip. People learn in a much more complex way; people learn through their worldviews, which are always present, and constitute an epistemological structure, much more than a few alternative conceptions. Even more, most of the time, worldviews do not match scientific paradigms, so it is a mistake to think that we can teach without knowing or without taking account of the fact that people see the world in many different ways than the one we want to teach. Astronomy Education must be more significant in the future than simply teaching Astronomy, if we want people to live their worldviews including scientific elements.

Astronomy Education, Astronomy for Education, must be a dynamic and professional activity, developed by specialists who must be aware of the relevance of worldviews. An activity respectful of the diversity and identities of human groups, with deep roots in scientific knowledge, with a vision of the future but with awareness and respect for the past, with rigor as well as epistemological humility, and conscious of the ethical responsibility that concerns us as scientists and educators towards the society that we integrate and that we collaborate in the construction of more genuine ways of seeing the world.

We must be aware that every time we educate in Astronomy, we bring to people new elements to transform their worldviews. It is not an invasive way if we design the didactical structure thinking in "him", in each one of the learners; it would be invasive, imperialistic, totalitarian, if we teach the same, independently of in which part of the world and with what people we will work. We would be only teaching components of a scientific paradigm; we would not be educating through Astronomy.

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What all Teachers Should Know about Astronomy Education in Primary and Lower Secondary Education

Speaker: Akihiko Tomita, Wakayama University, Japan

Contents of school education are defined by curriculum standards in each country or territory. Though it is not easy to meet all the demands, the standards are based on years of discussions, therefore, the standards indicate what all teachers should know; we already have the answer. On the other hand, there are difficulties teachers face in teaching astronomy. Based on papers and interviews with teachers about their work in Japanese classrooms, I will present what general teachers in Japan want to know about astronomy for their teaching work. The presentation focuses on primary and lower secondary education because many teachers in the levels are not always well versed in astronomy, therefore, what they want to know indicates what all teachers should know from the perspective of teachers.

Talk link: https://youtu.be/0ABERfDdU_4

Astronomy is popular among all ages. Students are crazy about black holes, extraterrestrial intelligence, space missions, and many others. Social capital for astronomy education is abundant. In Japan, more than 350 planetariums are open to the public in all areas including rural areas, more than 200 thousand projections are made a year, and more than 8 million people visit there a year. However, when it comes to school science classes, both students and teachers are not good at the content. Except for a few teachers who are good at astronomy, many teachers have a hard time teaching astronomy. This presentation is a summary from a teacher's point of view, not a student's point of view. Thus, the first research question was set like this: What do teachers who are not good at astronomy have trouble with in their classes?

Method: First, build relationships with the teachers and then proceed with the interview. Then, collaborating on actual classroom planning based on this research. If we just list the problems, it has already been done in many research publications. If this is all we do, it will be reinventing the wheel. Today, my presentation is the first result of the interview.

Preliminary results: These are some feedbacks from preliminary interviews. The first is the difficulty in direction and location. "*The students need to think about the direction, time, position of the Sun, and phase of the Moon at the same time. But these topics are not so rooted in students' daily lives.*"

Some surveys have shown that thinking about positional relationships is linked to ability in mathematics rather than science. This is also connected to map-based learning in social studies. Cross-curricular teaching and STEAM education are now very popular among science education as well as astronomy education. I believe that advice from this perspective would be very useful for teachers who are not good at astronomy. Not only math and technology, but astronomy education can also be linked to history, geography, literature, art, craft, music, health education, moral education, and international understanding education.

Next is the issue that experimentation can lead to misunderstanding. *The textbook says, "The phase of the Moon changes because the positions of the Moon and the Sun change." However, many students think that this is due to the change in the positions of the Moon and the Earth from the experiment of looking at a lighted ball, and I do not fully understand this.When I tried to show a quarter moon and a crescent moon in the experiment using a ball and a light, I moved the position of the light, which made the students think that the position of the Sun also changed.*

This is a great opportunity. Rather than being pessimistic about getting the wrong concepts and the confusion, here is an issue that needs to be carefully researched: what students looked at, what students thought, what students concluded, what students were confused about, and what students came up with. Rather than whether it was correct or not, we should encourage students' way of thinking. We can then make a new class plan based on the above investigation. There are a wide variety of ideas as to what causes the phases of the Moon. Some science education researchers may just be disappointed to see the results of such a survey. Rather, we should investigate what kind of moon the students see in their daily lives, no matter how ridiculous it is, how they interpret it, and how they connect their interpretation to the moon they actually see. Primary and lower secondary school teachers are good at such investigations and would also enjoy doing it, regardless of whether they are good at astronomy or not.

In a classroom that nurtures the thinking ability, thanks to the classroom teacher's great PCK, students are going to the next step to explore further. *As the students' understanding of the Moon phase increases, a new question arises: "Why does the Moon move like that? This is a question that is not related to the textbook description. How should I respond to such a question?* This episode shows the new next step after "what about this kind of material," and "what about this kind of teaching method?" The teacher was very confused. Of course, it is not true that this kind of comment by a student is a getting-off subject just because it is not written in the textbook. First, researchers in astronomy education can appreciate the teacher's high-level classwork. How to respond to students' high curiosity is not easy, of course. Not by just transferring knowledge, but by creating a new exciting environment based on the students and the class atmosphere, this is a new issue for joint research between researchers and teachers.

This presentation is the first result of some interviews, so please wait for some time to show the result of the whole research. Instead of that, here I would like to introduce a new project to exchange and discuss together about the difficulties the teachers have faced in school classes and how they have motivated students, created a cheerful class, and brought out students' thinking ability and scientific views. For teachers who are not good at astronomy, we should not just dump knowledge and provide physical materials, but also share ideas that will make the teacher feel positively, "What? This is the kind of classroom creation I am very good at!" or "Wow! This is the kind of classroom creation I can do from now on!"

My colleagues and I are preparing a project called New Astronomy Day in Schools as a platform, which will host this project. The website will be accessible in September.

Challenge in Teaching Astronomical Causes of Seasons in the Tropics

Speaker: Noorali Jiwaji, Open University of Tanzania, Tanzania

Tropics, especially close to the Equator experience mild changes of temperature during the year, so seasons are marked primarily by the bimodal rainfall pattern, which is broken by proximity to ocean, resulting in weakly defined seasonal changes. Astronomical causes of seasons are taught using the northern "gospel" of summer, winter, autumn and spring without understanding the regularity and profound seasonal changes experienced away from the tropics. Hence the local seasons as well as its astronomical causes are not properly understood and misconceptions and wrong ideas are introduced at a young age. We show how this problem is reflected in Tanzanian learning, especially when local language (Kiswahili) terminologies are used to describe seasons.

Talk link: `https://youtu.be/oRmpIR4eIME`

Astronomy is taught in schools primarily as a science subject, in particular, Physics. It is also taught as part of Geography for its influence on weather and seasons under the Solar System topic with additional topics such as eclipses, tides, remote sensing are also included.

Tanzania has a colonial legacy from millennia with Arab traders trading with dhows to the eastern African coast making use of the Monsoon winds and navigating using the stars. The Arab and Bantu culture assimilated to produce the Swahili culture and the Kiswahili language that is now used across east and central Africa. The German rule from 1880's and the British Protectorate from 1916 imposed foreign culture and provided education for clerical jobs requiring rote learning that is practiced to date. Teaching materials used today are derived from colonial materials.

Teaching in Schools: In Tanzania Astronomy topics are introduced in Primary school in Standard 3 (Grade 3) (TIE, 2019b). The local Kiswahili language used as a medium of instruction introduces misrepresentations from translations done by authors not familiar with Astronomy. This has also introduced a big confusion in planet names, in spite of the rich Kiswahili Astronomy terminologies from ancient sailors compiled recently by Knappert, 1998.

In Secondary schools, where the medium of instruction changes to English, Astronomy is included as a chapter in Physics with a previously weak chapter (TIE, 1996) that included misconception, which has how been included in a more thorough chapter on Astronomy at the very end of the new Physics textbook (TIE, 2019c). The inexperience of teachers in Astronomy glosses over the topic and students have to learn it by rote. In Geography, the Solar System topic is introduced in Form 1 (Grade 8) and Form 2 (TIE, 2019a) with a focus on the four standard seasons using 2D diagrams to show a 3D system with Earth's axial tilt not easy to understand how the four seasons arise. Misconceptions such as "the North Pole faces the sun directly" and wrong explanations such as "temperatures are hot due to long duration of sunlight" confuses the learner further. The standard four seasons of Summer, Winter, Autumn and Spring are explained without any association with local experiences of the climate. Close to the Equator only two prominent seasons can be experienced: Hot and Rainy. Elsewhere in the tropics such as in Tanzania (1oS to 10oS), a bimodal rainfall pattern gives three main seasons: Hot, Short Rains, and Long Rains which cause wide local variations due to relief and ocean.

Study on understanding of Astronomical connection with seasons: Knowledge and understanding of the four standard seasons and its relation to Astronomy for the annual cycle was studied using a questionnaire. True and False options were provided together Do not Know and Do not Understand options were also given. The questionnaire was distributed to nearly 200 Secondary school teachers and adults for online responses and by hard copy to nearly 200 Secondary school students from different schools across Tanzania, who had passed through the seasons topic in their Geography classes. Even after several reminders and urging, only 10 responses were received from adults including teachers. However, responses from 170 students were received.

Lack of understanding: Lack of responses from adults is seen as a reluctance to show their lack of understanding long after they left school. However, the results obtained from students were useful. Though Summer was well connected (90%) with the hot season, the other three seasons were not as well known. Questions about the time of year for each of the four standard seasons showed a wide range from January to December for all seasons, although they know the time for long rains. The cyclic nature of the seasons was understood by about half the respondents. Cause of hot temperatures was well connected with decrease with altitude, but there was a misconception (70%) about the closeness of the Sun to Earth even at Noon as causing it to be hot.

Our study shows that among students there is a lack of understanding of the four standard seasons and their astronomical causes. To alleviate this problem special in-service training of teachers is needed urgently which has begun in collaboration with experts from the Network of Astronomy School Education (NASE). Two training sessions have been held and more are planned. Corrections of school texts are being pursued for local Kiswahili language materials in Primary schools and producing radio programs for the public. Creation of the Astronomy lexicon related to its concepts will benefit a wide population across eastern and central Africa. Secondary school Geography textbooks also need to be corrected and improved to include local climate variations; with the four standard seasons being stressed to be for high latitudes and use their clear demarcations to show the cyclic Astronomical nature of seasons. Clear understanding of how local seasonal effects can be understood will be essential to prepare the public for the expected climate changes to be tackled.

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Challenge-based Learning for Astronomy Education

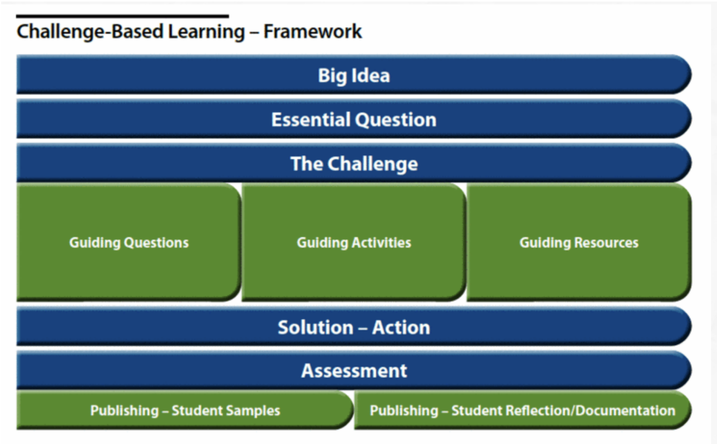
Speaker: Jasmina Lazendic-Galloway, TU/e innovation Space, Eindhoven University of Technology, Netherlands and School of Physics and Astronomy, Monash University, Australia

Challenge-based learning (CBL) has emerged in the last decade as a response to the complexity of problems facing society in the 21st century. This way of learning prepares students for the future of multi- or inter-disciplinary work and decision-making, with emphasis on self-awareness and teamwork, among other things. Students work on complex open-ended projects, often directly related to societal challenges in collaboration with "challenge owners" such as government or societal organisations, university researchers or industry. CBL has been applied for learning in high-schools, universities, companies and scientific organisations such as CERN. I would discuss ideas how one could use CBL to tackle societal issues through astronomy education.

Talk link: https://youtu.be/jwD-xCSR_c0

How to use challenge-based learning to tackle societal issues through astronomy education?

Challenge-Based Learning (CBL) has emerged in the last decade in response to school students' disengagement in classes and desire to provide them with more challenging coursework that is linked to real-life context (Apple Inc 2009). CBL involves active participation and collaboration with experts across different levels (teachers, industry, community members) in order to foster deeper learning and where students can come up with ideas of how to make a difference. While it has been extended further to higher education and work-based learning to tackle the complexity of problems we face today in society and workplace, the fact that CBL requires exploration of topics from multitude of perspectives and disciplines makes it suitable as a learning approach at any level. I would discuss ideas on how one could use CBL approach to tackle societal issues through astronomy education, starting with one of the topics from Big Ideas in Astronomy "We must preserve the Earth, our only home in the Universe".



Apple's Framework for Challenge-Based Learning

An example: Big Idea: Light pollution and its effect on humans and other living organisms. *Generate "essential question"*: What is the impact of light pollution on human life and human activities such as astronomy? *State the challenge*: Increase awareness. Create opportunities for dialogue between the key players. Create ideas for technical solutions. Create ideas for societal solutions. *Design process - Guiding questions/activities/resources*: Students identify the knowledge they will need to understand to develop a solution to the challenge, e.g.: What is light pollution caused by? What are the issues/barriers in changing the current practices? Identify activities needed, e.g., conduct experts surveys, make games, do calculations etc. to acquire the knowledge needed. Identify resources needed, e.g., podcasts, websites, videos, databases, contact information for experts. *Identify solution/action*: For example, make a campaign to inform and/or convince family, peers, or community members about the need for change. *Assessment (publishing/reflections)*: For example, students document their experience using audio, video, and photography and can be provided with a series of prompts for final reflections about what they learned about the *subject matter and the process*. Students can share their findings with everyone online, or at a school event with other students and/or the whole community.

The Significance of Doing Practical and Experimental Astronomy

Presenter: Carles Schnabel & Rat Parellada[1], Planetari Fora d'Òrbita and Observatori Astronòmic Garraf, Spain

Astronomy is explained in an encouraging but theoretical way. They provoke sensations of admiration in the face of violent and spectacular phenomena. Their meaning is seldom understood and contextualized. We need to raise questions about things we can see, instead of giving answers about what we never see with our own experience. Everyone has access to the sky and his movements. Main stars are easily observable and measurable. You can experiment with your own body and simple materials. Once the basic concepts are well established, we will be able to face them with the guarantee that the receiver will want to achieve a clear and contextualized understanding of the concepts of the physics of the universe.

Poster link: https://youtu.be/8UuZFDLPb_Y

Astronomy is usually explained in a very theoretical way. This approach can be very exciting. Kids and teens love to learn more about the Big Bang, black holes, galaxies, exoplanets, Martian rovers, and more. However, it is a knowledge that, with a few exceptions, remains very superficial in the receiver. They provoke the characteristic sensations of admiration in the face of violent, spectacular and large-scale phenomena. But their meaning is seldom understood and contextualized. They are "out-of-place" knowledge.

But astronomy admits of a much more practical approach, from the receiver's own experience. Everyone has access to the sky: all the world's population, all cultures, all ages, and all genders. The movements of the sky and the main celestial objects are easily observable and measurable without even the need for instruments. The observation of the Moon and the Sun, for instance, occurred thousands of years before the establishment of calendars.

This allows you to practice astronomy with your own body and with simple materials from the immediate environment. This type of practical astronomy, which can be done both day and night, is at the bottom of cognitive processes. Once the basic concepts are well-established, we will be able to face them successfully and with the guarantee that the receiver will want to achieve a clear and contextualized understanding of the deepest concepts of the physics of the universe, in astronomy. We need to raise in the receiver the questions about the things he can touch and see, instead of giving him answers about what he has never seen with his own experience.

[1]https://planetari.cat/

We propose to mark some footprints in the school yard: North-facing footprints are used to observe the shadows of the sun throughout the day and at different times of the year. Other south-facing footprints are used to observe the positions and phases of the Moon throughout the month and throughout the year. The meridian (line from north to south) and the parallel (line from east to west) drawn on the ground are used to compare the shadows that occur on the ground with those that are drawn on a globe.

With these simple resources, questions will be generated such as: Why do the Sun and the Moon always move in the same direction? Why do the Sun and the Moon change in height during the day, throughout the month, or throughout the year? Why is the Moon not visible always? Why is it sometimes seen in the morning and sometimes in the afternoon? And so on. They can be invited to continue with similar observations at home, with their family, to observe the movement of the night sky: stars and planets. This simple observation of the sky will raise a lot of questions about distances, type of stars, how are they distributed in space, etc. This is only an example. Other ideas we worked out can be seen at https://tuit.cat/tVx9q. These are catalan spoken videos, but they are also subtitled in English.

Astronomy Education Outreach with Younger Community through an Online Service-Learning Approach

Presenter: Othman Bin Zainon, Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia

Astronomy involve concepts that related to everyday phenomena. Astronomy is also about the science of celestial observation and evaluation involving celestial objects that happened outside the earth's atmosphere. In Malaysia, astronomy topic has been adapted in various of school levels especially in science and mathematics syllabus. However, some of the younger communities' have problem in understanding about the basic concept of astronomy. Therefore, Universiti Teknologi Malaysia Astronomy Co-Curricular students have carried out an online Service-Learning approach for transferring the astronomy knowledge to the younger students. This innovative astronomy service-learning approach consists of five activities namely Astronomy Talks, Demonstration, Hands-on, Quiz and Competition.

Poster link: https://youtu.be/o_xxZBbj3tw

Astronomy is about the science of celestial observation and evaluation involving celestial objects and events that happened outside the earth's atmosphere. In Malaysia, astronomy has been adapted as one of the subtopics in various school levels starting from kindergarten, primary school, and secondary school especially in science and mathematics syllabus. However, some of the younger communities' have problems in understanding the basic concept of astronomy. Therefore, Universiti Teknologi Malaysia have designed an Astronomy Co-Curricular course for the university students. In the pandemic situation today, the students must carry out an online Service-Learning to transfer the astronomy knowledge to the younger students.

Service-learning pedagogies combine learning goals and community service in ways that can enhance both student growth and the common good (Bandy,2001). Service learning is a combination of teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities". The objectives of this project are to increase understanding of the concept of astronomy to the younger students and to increase the younger student's interest in science through astronomy knowledge transfer. This study illustrates five innovative astronomy activities that used to enhance the learning potential of service-learning pedagogy. The five activities are Astronomy Talks, Demonstration, Hands-on, Quiz and Competition.

Before the Covid-19 pandemic, the service-learning program was conducted face to face at the chosen community. Now, because of the Covid-19 situation the program was conducted through a social media online platform. A few programs were organized by the astronomy co-curriculum course students.

A pre-survey was conducted before the online outreach program started. The result shows that more than 60% of respondents do not understand the knowledge of the astronomy presented topics. After the online program a post survey was carried out and the results showed that more than 80% of respondents have the knowledge of astronomy topics presented to them. In conclusion, the systematic planning of activities using the service learning approach and five innovative activities can help the young community to understand and enhance their knowledge in astronomy through a selection of a few selected topics.

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Teaching Undergraduate Astronomy Classes with Active Learning Strategies

Presenter: Newton Figueiredo, Universidade Federal de Itajubá, Brazil

Active learning methods have been successfully used to teach science, technology, engineering, arts and math (STEAM) subjects at all levels of formal education. In this talk I will show what can be accomplished by combining three of these methods - flipped classroom, just-in-time teaching and peer instruction - to teach astronomy to undergraduate students enrolled in STEAM courses. I will also present effective ways the instructor can use, under this approach, to assess the students' learning without written exams.

Poster link: `https://youtu.be/MTihpq5l2Bs`

Active learning methods have been successfully used to teach science, technology, engineering, arts and math (STEAM) subjects at all levels of formal education (e.g. Crouch & Mazur, 2001; Freeman et al., 2014). Those methods comprise a wide range of different approaches that have in common the search for an active role for the students in the teaching-learning process, as opposed to a passive posture that characterizes lecture-based teaching (Bonwell & Eison, 2001).

Although each of these methods has been developed independently, the literature reports positive results for the combined use of more than one active methodology in real classroom situations. Araujo and Mazur (2013), for example, present a successful application of peer instruction and just-in-time teaching in higher education. Furthermore, the use of active methodologies in higher education institutions has been shown to be an effective strategy to reduce dropout rates and significantly improve student learning (e.g. Watkins & Mazur, 2013). The effectiveness of this type of approach can significantly increase when face-to-face teaching is associated with Information and Communication Technology resources (Hogarth, 2009).

We have been combining three of these methods - flipped classroom (Abeysekera & Dawson, 2015), just-in-time teaching (Novak et al., 1999) and peer instruction (Mazur, 1997) - to teach an introductory astronomy course to undergraduate students majoring in meteorology, physics and chemistry at a research university in Brazil since 2017. Before class, students are assigned tasks such as watching a video, running a computer simulation or answering a quiz in the virtual learning environment. During class, they have peer instruction classes and problem-solving group activities. After class, they are assigned hands-on activities. All tasks are assessed by the instructor or by their classmates, but there are no written exams.

A quantitative analysis of the interaction among the students in each peer instruction session is performed by means of a binomial test (Figueiredo & Figueiredo, 2019), and also by a comparison of the overall class score before and after the interaction. These analyses show a significant increase in student learning when combining flipped classroom, just-in-time teaching and peer instruction (De Paula et al. 2021).

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The Transferential Relationship from the Discourses between Children and Monitors in an Observatory

Presenter: Gleici Kelly de Lima, UNESP / Bauru, IFC / Rio do Sul, Brazil

The main purpose of this research was to interpret the discourses of the transferencial relations between children and monitors teachers in an astronomical observatory. Were concepts of transference and discourse is introduced highlighting the psychoanalytic aspect as reference to understand the teacher-student relation, during a class visit in an astronomical observatory. Is theoretically and methodologically based on Education, Psychoanalisys and Astronomy Education references. The results obtained by the analysis of the four lacanian discourses of the unconscious point to traces of three approaches to the discursive transferential relationship between monitors and children at the observatory: authoritarianism, excitability and otherness.

Poster link: https://astro4edu.org/siw/p75

The main objective of this research was to interpret the transference relations discourses between children and monitor teachers of an astronomical observatory. Introducing the concepts of transference and discourse [1], highlighting the psychoanalytic aspect as a reference to understand the teacher-student relationship, during a class visit to an astronomical observatory. The focus of study was the Didactic Observatory of Astronomy, "Lionel José Andriatto" at Unesp in Bauru, São Paulo, Brazil. The speaking subjects of this research are children in early childhood education, who visited the observatory, as well as the teacher assistants who guided the visit. Data collection was made through observation, using audiovisual recording and records in a field diary, later transcribed, so this study is based on qualitative fieldwork [2].

In Lacanian theory, language is an independent system that binds people together. In addition to being an instrument of human control, it is the structuring of social ties, a wordless mode of social engagement. In Lacanian theory, discourses are ways of using language as a social link, building on the signified part of the sign that produces the discourse. As discourses are unconscious and wordless, the signifiers in them represent sound, since language is composed of sounds. When these signifiers are articulated, they produce what Lacan calls meaning [3]. We started from this assumption using the metaphor of Lacan's theory of four unconscious discourses: the Master's, the University's, the Hysteric's and the Analyst's, helped us to interpret the discourse and attain, even partially, the understanding of the transference relationship between teacher assistants and children.

Using Lacan's four discourses in our final analyses made it possible to find traces of transferential engagement between the subjects. These findings allow us to define at least three approaches that outline the demands of children and assistants. First, we have the Authority Approach, paving the way for a more Cartesian, dogmatic relationship, and promoting literacy through the "clear ideas" of science, constantly demanding answers from children. Second, there is the Excitability Approach, which relies on the hysteric's discourse, with a more meaningful transference, grouping children together under the rhetoric of astronomy, exciting, and urging them to seek knowledge, proposing questions and encouraging their participation. The third is the Alterity Approach, which describes a relationship more concerned with the construction of knowledge in the other, as when the assistants invested more in encouraging children to speak, enabling a scientific literacy that considers alterity.

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Scaffolding from Astronomers: Delivering Lessons to Schools and STEAM Education

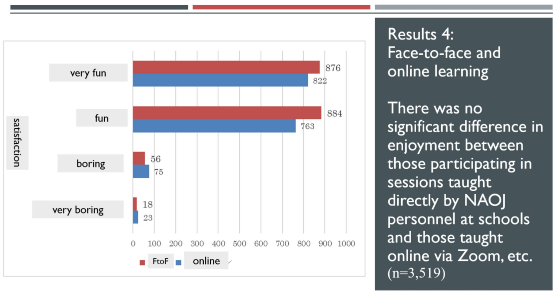
Presenter: Hidehiko Agata & Tokiko Fujita, National Astronomical Observatory of Japan, Japan

National Astronomical Observatory of Japan (NAOJ) launched the 'Fureai Astronomy' education and outreach program in 2010. This is an activity in which NAOJ staff members give classes on stars and universe at elementary and junior high schools, with the aim of getting to know each student individually. In the 2020 fiscal year of the Corona pandemic, in addition to the traditional delivery of classes to schools, online classes using Zoom, etc. were also conducted. In the case of online classes, it is possible to participate from outside Japan. In addition to a discussion of the differences between face-to-face and online, this talk will present examples of scaffolding from astronomers that can be expected to lead to STEAM.

Poster link: https://youtu.be/_Q16-XFuYE0

"Fureai (=Friendly) Astronomy" (https://prc.nao.ac.jp/delivery/) is a NAOJ outreach project that started from a single idea: What interesting reactions might occur if children had

Face-to face lecture-type vs Zoom online



Face-to-face (FtoF) vs online learning

the opportunity to meet actual astronomers? 2021 will mark the twelfth year of its implementation. Due to the COVID-19 pandemic, in 2020 we conducted online sessions in addition to our customary in-person sessions. Hosting online sessions allowed international participation, so we were able to hold 99 sessions in total (69 domestic and 30 overseas schools), with 64 NAOJ's astronomers serving as instructors.

There was no significant difference in enjoyment between those participating in sessions taught directly by NAOJ personnel at schools and those taught online via Zoom, etc.

Participant satisfaction increased in classes with easy-to-understand content and an appropriate level of excitement. The higher the prior interest in astronomy, the more it increased after implementation (prior guidance is important). Satisfaction (fun) and change (increase) in interest showed positive correlations with difficulty (easy-to-understand). Small class sizes tended to increase satisfaction.

90% of children and students want to engage with astronomers again. Please consider implementation at your university or facility. The "Fureai Astronomy" has inspired into the IAU's "Meet the IAU Astronomers!" (https://www.iau.org/public/meettheiauastronomers/).

Discussion summary

Néstor Camino and Carmelo Presicce, our invited speakers, set the stage; Carmelo helped us to connect with the experience of the Lifelong Kindergarten group at MIT Media Lab; he opened a reflection about how to cultivate creativity in STEM learning through learning communities connecting with Astronomy learning practices. Néstor discussed Astronomy Education as a means to transform our worldviews pointing out how Astronomy Education - through a connection with the physical sky - could contribute to the construction of world views based on solidarity, respect of diversity to prepare for a peaceful future. Akihiko Tomita interviewed teachers in Japan and he highlighted the teacher's perspective on STEM teaching/learning and possible criticalities. Noorali Jiwaji discussed his experience in Tanzania where seasons are taught as in Europe despite the fact people cannot observe such seasons. Jasmina Lazendic Galloway talked about a particular way to interpret change in STEM learning: Challenge-based learning (CBL) describing ideas how one could use CBL to tackle societal issues through astronomy education.

The discussion was very lively and engaging. We realized that we are facing similar issues in different countries but also across disciplines (e.g. astronomy and computer science). We also realized there are so many interesting and diverse practices in teaching and learning in Astronomy; the general conclusion of this session is that in the knowledge society, it is a matter of democracy to allow children to connect with science, to develop their own ideas, and to act in our society as an active citizen. This global network of goodwilling people can really make a difference nurturing this community, cultivating personal practices and sharing them with the broadest community. This network has an important role: to help people (teachers in particular) to connect and to share ideas, cultivating a stronger and more connected community.

Teaching with Astronomy Exhibits

Session organisers: Giuliana Giobbi, INAF-OAR - National Institute for Astrophysics, OAE Center Italy, Italy and Renate Hubele, Haus der Astronomie/ZAH, Heidelberg University, Germany

Session overview

This session focuses upon the use of easy-to-reproduce exhibits in contemporary interactive teaching of Astronomy in schools and for public outreach purposes. We invited a few astronomers and educators from various scientific institutes around the world, to find out about tools, ideas and techniques, and two speakers engaged in inclusive teaching, with exhibits dedicated to people with visual impairments. Wolgang Vieser, from the ESO Supernova Exhibition Centre, Germany, focused on a couple of workshops he and his colleagues have created, for introducing a few concepts of optics and astronomy to secondary school pupils. Rick Tonello, from the Gravity Discovery Centre located in Gingin, Western Australia, described their Space-time Simulator, an impressive exhibit that illustrates how gravity and mass induced space-time curvature work. Farprakay Jiarakoopt, from the National Astronomical Research Institute of Thailand, described two exhibits in detail, which can easily be reproduced and are useful to be applied in classroom activities for more effective lessons about basic concepts of astrophysics. B.S. Shylaja, from the Jawaharlal Nehru Planetarium of Bangalore, India, explained the use of a clock and another exhibit for a simple explanation of time, phases of the moon, and the orbits. Nicolas Bonne, from the Tactile Universe Outreach Centre at the University of Portsmouth, UK, illustrated the tactile models of galaxies they produced and used mainly with groups of blind and visually-impaired pupils and people. Amelia Ortiz Gil, from the University of Valencia, Spain, showed us the 3D tactile model of Mars prepared on the occasion of the "Inspiring Stars" Exhibition organized for the 100 years of IAU. We also had two poster contributions from Tan Jyh Harng (Singapore Science Centre) and Sitaram Bettadpur (Kolkata, India).

Engaging through DIY Workshops to Discover Scientific Principles and High-Tech Applications

Speaker: Wolfgang Vieser, European Southern Observatory, Germany

Effective learning relies on the involvement of as many senses as possible and a positive learning environment. ESO Supernova Planetarium & Visitor Centre, of the European Southern Observatory (ESO), is in high demand as an out-of-school learning location offering a varied education programme. In this talk, I wll explain how we engage students with the discovery of curriculum-related physical principles through hands-on workshops that make use of low-cost materials and easy to make, portable setups. With the example of our Telescope workshop, I will illustrate how both basic scientific principles and applications of modern engineering, e.g., for the Extremely Large Telescope of ESO, can be investigated by the students.

Talk link: https://youtu.be/F2Ifo7OmbFY

The European Southern Observatory (ESO) is the foremost intergovernmental astronomy organisation in Europe and well known for designing, constructing and operating powerful ground-based observing facilities. At its Headquarters in Garching near Munich, ESO is also running the ESO Supernova Planetarium & Visitor Centre that engages with more than 60000 visitors a year. The ESO Supernova (ES) is not only a free astronomy centre for the public with a state-of-the-art planetarium, a huge exhibition floor and seminar rooms for conferences, talks and workshops but also an out-of-school learning location that attracts approximately 9000 pupils (K-12) a year coming from 11 different countries (numbers from 2019). The permanent exhibition "The Living Universe" features 13 themes covering the science and technology behind modern astronomy, encompasses 2200 square meters of barrier-free exhibition space and is bilingual (English & German) throughout. The content is presented to the visitors in many different ways: interactive digital and physical exhibits, video and audio clips, large-scale images and models as well as panels and touch screens so that visitors can individually choose the depth of information.

Many studies indicate that there are positive long-term impacts of museum experiences and that learning actually happens in science centres (e.g. Falk et al., 2014). In contrast to everyday school life, "Scientific field trips to science centres can generate a sense of wonder, interest, enthusiasm, motivation, and eagerness to learn, which are much neglected in traditional formal school science" (Eshach 2007, p. 125). A field trip for pupils K-12 to ES includes a visit to a planetarium show, an age-appropriate guided tour of the exhibition led by an education specialist, a trained student or staff member from ESO's science or engineering department and an inquiry-based workshop led by an educator. This programme is free of charge and allows authentic experiences

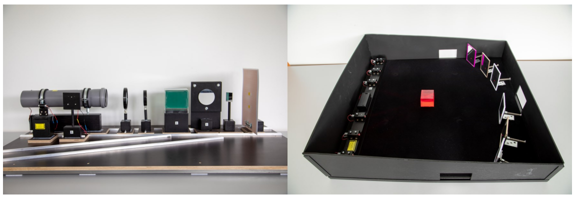


Figure 1: The setup of the "Catching Starlight" workshop (left) and the activity to introduce modern telescope technology to the pupils (right)

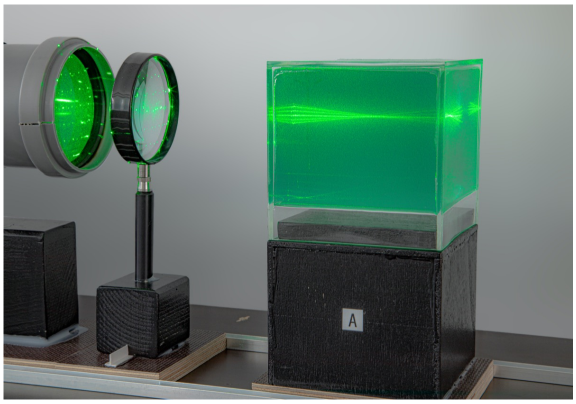


Figure 2: Focusing of parallel laser rays via a magnifying glass is made visible in the cube of coloured synthetic resin.

with science and technology in the context of autonomous, active, pupil-centred learning. It has been shown that this way of learning elicits extended engagement and self-directed inquiry (Allen, 2004) and supports intrinsic motivation, interest in science, self-confidence and science learning achievement (DeWitt & Storksdieck, 2008). Observations of school groups during a guided tour at ES show that especially the interactions with the guide, the possibility to ask questions and to have discussions among themselves, leads the pupils to be more cognitive and emotionally engaged during the visit than they were in the classroom. Since studies (e.g. Henriksen & Jorde, 2001) indicate that students' interaction with exhibits can generate and facilitate misconceptions, ES's interactive exhibits are part of the guided tour, so that the pupils already have a conceptual understanding of the exhibits before they go exploring on their own later on.

For the inquiry-based workshops, the essential design factors for exhibits, that allow a playful and exploratory discovery of scientific principles, and the curriculum relevant requirements are taken into account. The workshop design allows multiple opportunities for exploration and collaboration and also features phenomena that contrasted with pupils' previous experiences. The workshops also include cognitively challenging parts, allowing for internal differentiation and adaptation to different learning speeds. They are implemented in such a way that they can be easily replicated, repeated and enhanced in educational institutions or at home for low cost. The construction manuals as well as the student and teacher worksheets can be downloaded from ES's website.

The workshop "Catching Starlight" for example covers large parts of the curriculum topic "Optics". The objective is to find out more about lenses, how to classify and to combine them to build an optical device - in this case different telescope designs. When experimenting, additional phenomena can also be investigated, such as why the orientation of an image changes when seen through a lens, how to mix light of different colours, why an obstacle in the beam path like a secondary mirror does not lead to an incomplete image. The workshop consists of many activities that enhance scientific understanding via the method: predict, observe, explain. Like all our workshops, this one is also made of everyday materials (see Figure 1). A laser cannon, made out of a drainpipe, a laser pointer, a diffraction grating and a magnifying glass, generates many parallel laser beams with which the discovered principles can be validated and the focusing of light can be perceived as a three-dimensional process when the laser rays become visible inside the light ray block made of coloured synthetic resin (see Figure 2).

Although the used gadgets and implemented methods are engaging, the sole use of "old-style" telescope designs to find out more about optics is not particularly exciting for pupils. We therefore designed additional activities to make pupils familiar with modern telescope technologies, namely segmented mirrors and active optics that are used in ESO's Extremely Large Telescope. Here, the pupils need to focus parallel laser beams with the aid of six single flat mirrors (see Figure 1). The mirrors stick magnetically to the surface, can be moved and adjusted in their angle of inclination (with the help of "actuators"). Different ways of focusing the light are possible: prime focus, Cassegrain focus or Nasmyth focus.

The "Catching Starlight" workshop takes about 60 to 90 minutes in total and is very popular for pupils aged 10 – 15 years but is also extensively used for teacher training.

In total the ESO education programme offers six different workshops for different age groups (K-12). More workshops are in preparation as well as a professional evaluation of the workshops.

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Space-time Simulator Demonstration

Speaker: Richard (Rick) Tonello, Gravity Discovery Centre, Australia

In 1915, Albert Einstein published his celebrated "The General Theory of Relativity", the concept of curved space and warped time caused by the mass of an object was only within the grasp of professional physicists and well out of reach for the everyday layperson or school student. Using simple construction materials and methods, the "SpaceTime Simulator" (STS) has changed that by giving the teacher and student, the ability to observe a "simplified" version of Einstein's four-dimensional Spacetime. Using different mass spheres, the STS can now demonstrate and observe how objects are affected by the curved geometry caused by the mass of objects. A number of demonstrations can be performed utilising Space Time Simulator (STS). From demonstrating how a photon of light travels in a straight line with no mass present to how matter is "spaghettified" by the gravitational interactions of a simulated Black Hole.

Talk link: https://youtu.be/1bRyg804BN8

"Matter tells Space(Time) how to Curve; Space tells Matter how to Move".
-John Wheeler-

In 1915, Albert Einstein published his celebrated "The General Theory of Relativity", the concept of curved space and warped time caused by the mass of an object was only within the grasp of professional physicists and was well out of reach for the everyday layperson or school student.

This apparatus has changed that by giving the teacher and student the ability to observe a "simplified" version of Einstein's four-dimensional Spacetime. By the use of different mass spheres, they can now experiment and observe how objects are affected by the curved geometry caused by the mass of objects.

Equipment: The SpaceTime Simulator (STS) is very simple in its construction. The Gravity Discovery Centre's STS is made from an old trampoline frame that was recovered from a local recycling centre. The frame may be constructed from any number of materials (steel tube, aluminium or timber) depending on its availability and the skill of the person constructing the STS.

The circular design has proven to work the best, given when a mass is applied to the fabric, it produces an even curvature rather than a strange curvature produced by a square/rectangular frame. However, a square/rectangular can still work well enough to demonstrate curved Space-Time. The Fabric used is Lycra® or Spandex® . This material is durable, has the ability to stretch a great amount and return to its original form. One addition to the fabric would be grid-lines that may represent the dimension of Time. Time can be observed to remain constant (i.e. no stretching or compressing) when there is no mass applied and "stretch" when a mass is applied to the fabric.

The test masses (planets & stars) can be anything from golf balls, tennis balls, billiard balls, bocce balls, shot-puts/solid iron balls and even ten-pin bowling balls. A range of masses is ideal, a heavy mass to represent a star, an intermediate to represent a Super Jupiter/Jupiter planet, and numerous, lighter masses for small planets.

Demonstrations: As the video shows, a number of demonstrations can be performed utilising STS. From demonstrating how a photon of light travels in a straight line with no mass present to how matter is "spaghettified" by the gravitational interactions of a simulated Black Hole. The STS has been in use at the Gravity Discovery Centre for well over 15 years and has demonstrated to countless people how Gravity is an acceleration along the curved geometry of Spacetime.

We imagine that Albert Einstein would have been delighted to see his complex theory demonstrated in a manner that is understood by people of all education levels and ages.

Designing an Astronomy Exhibition to Support Outdoor Education for School

Speaker: Farprakay Jiarakoopt, National Astronomical Research Institute of Thailand

The astronomy exhibitions in Thailand were designed with the contents related to the basic education core curriculum in mind. The exhibitions feature interaction both via the use of technology and more traditional means to provide a better experience for the audience. The audience are encouraged to experience and promote inquiry to further explore the exhibits. The exhibition is produced in-house, therefore, visitors can easily deliver ideas of the exhibited equipment to apply with their activities in classroom. Our exhibition values lifelong learning and teaching, curiosity and inquiry, iteration and evidence, integrity and authenticity for sustainability. Examples of exhibition zones such as moon phases, scattering of light, and proof of the Earth's rotation by using the pendulum, etc.

Talk link: https://youtu.be/RM65P1iA0SU

The National Astronomical Research Institute of Thailand or NARIT is a research institute under the Ministry of Higher Education, Science, Research and Innovation. Its main missions are to carry out, support, and promote the development of astronomy and astrophysics in Thailand through research, public outreach, and educational activities. To raise awareness of astronomy, NARIT provides exhibition services for students and the general public across all regions in Thailand to explain the basic knowledge of astronomy by designing with the contents related to the basic education core curriculum in mind: Astronomy and Space. The exhibitions feature interaction both via the use of technology and more traditional means to provide a better experience for the audience. The audience are encouraged to experience and promote inquiry to further explore the exhibits. The exhibition is produced in-house including technologies, contents, infographics, etc. Therefore, visitors can easily deliver ideas of the exhibited equipment to apply with their activities in the classroom. Our exhibition values lifelong learning and teaching, curiosity and inquiry, iteration and evidence, integrity and authenticity for sustainability.

Objectives

1. To be a learning center in astronomy for local communities, schools, and universities to support astronomical academic services in school's curricula. And become the modern astro-tourism attractions of the region.

2. To be a learning resource where visitors can easily deliver ideas of the exhibited equipment to apply with their activities in the classroom.

3. To pursue knowledge and technology transfer in the field of astronomy.

Exhibition in AstroPark: The exhibitions feature interaction both via the use of technology and more traditional, emphasis on self-learning through devices and demonstration video. Furthermore, there are staff standbys to give more information to the visitor. There are two main exhibitions in AstroPark.

1. The Basic Astronomy Exhibition is inspired by basics of astronomy that can be seen in everyday life. Divided to 17 zones including Exploring the Solar system, Songs of the Universe, Moon Phases, Tides, Cosmic ray detector, Spectrum, Pattern in the sky, Aperture and Intensity, Seasons, Compare the weight on each planet, Your weight on other planets, Rotation of gas giant, Meteorite, Stellar evolution, The cosmic calendar, Foucault Pendulum, and Mission on Mars. In addition, the content and format of the exhibition are modified and updated to create a variety of learning.

2. The Astronomy Insight exhibition applied knowledge of fundamental physics and introduced in-depth astronomy data in the research field. There are 14 zones consist of Colors of light, Scattering of light, Refraction of light, The speed of sound, Pinhole Camera, Sundial, Liquid mirror telescope, Multiwavelength Astronomy, Infrared, Exoplanet exploration, Black Hole, Gravitational Lensing, Infinite reflections, and Astronomical phenomena.

Year-to-Date Operating Results: During July 2020 to July 2021 there were 160,945 people who visited the exhibition in AstroPark (temporarily closed due to COVID-19 in April to June 2021). And 1,160,290 people participated in the online events.


SEASONS


ASTRONOMY
ถึงเป็นสีฟ้า ?

Future development and service plans: NARIT has plans to develop online learning materials on astronomy, virtual exhibitions with interactive activities in these virtual tours. To keep up with the changing era that focuses on online platforms which makes it easier and faster to access as well as transfer an astronomy exhibition into simple astronomy learning tools. By using the exhibition as a prototype, then applying the working principle to modify and create more simple equipment that can be easily found for further interactive learning activities in the classroom.

Astronomy Exhibits from Classroom to Demonstration Models

Speaker: Shylaja B. S., Jawaharlal Nehru Planetarium, Bengaluru, India

Teaching astronomy requires a platform which is different from the conventional blackboard technique. In this talk I would like to show some of the tools I utilised to explain the concepts like Lagrangian points (for Trojan asteroids) the duration of the day on different planets (especially Mercury), the difference between the phases of a moon through the month and during lunar eclipse and many more. A demonstrative exhibition called "Science in Action" which generally covers physics and chemistry was conducted with 20 such exhibits and attracted over 2000 visitors. All these exhibits will be discussed.

Talk link: https://youtu.be/1ZF35GEB_V0

Astronomy is quite a difficult subject to grasp for people of all ages - the reasons are many. Although quite sharp in grasping the mathematical essence, many falter while applying it to the sky. This implies that a physical model is essential to get the complete understanding of the subject.

In the last two and a half decades of my teaching astronomy for various age groups I have found that the exhibits, after all, have emerged out of classroom teaching experiences. We, as teachers, created some tools within our reach, including different approaches like role-play to communicate the essence effectively. Such humble tools transformed themselves to exhibits in the science parks and exhibition halls in the planetariums and the like. We hold 3-day exhibitions called "Science in Action", where the table top prototypes were demonstrated by students in the age group 12 to 15. As many as 30 such demonstration models made a huge collection. However the metamorphosis into larger gadgets (tamper proof and weatherproof) demanded a different approach - money being the main constraint.

The globe with its axis parallel to that earth has been very useful for demonstrations on Zero Shadow Day.

The models exhibited in the 3-day exhibition include the Vertical model.

The "Vertical" model

Almost all the exhibits, irrespective of the country of origin, invariably have a horizontal plane as the reference. Models to demonstrate the phases of the Moon or eclipses or even planetary motion assume the orbital plane of the earth to be parallel to the table / horizon. We may have inherited this from traditional globe makers who had to accommodate the 23.5 degree tilt of the rotation axis of the earth. Thus the concept of seasons, or even day and night, is easily understood inside the classroom but not so efficiently in the real sky. While explaining this I had to tilt the globe to make my standing posture parallel to a doll (a piece of chalk) representing me on the globe. (This idea transformed into a huge globe positioned parallel to earth's axis in the science park) Such an exercise repeated over several years resulted in the design of a model which I am explaining now. The model is named "vertical" model for quick identification. This has the plane of the ecliptic *perpendicular* to the plane of the table. The earth goes round the sun in the vertical plane. This immediately drives home the point that we turn "upside down" after 12 hours. I have found this gadget extremely helpful and it has always been reserved for the first session of the first day in any workshop. It makes a good beginning to explain the gradual change in the visibility of constellations throughout the year and throughout the night.

The meaning of full moon, new moon can be easily explained here although there is no provision to mount an object as the moon. Here, in India, the names of the months are coined in a special way and thus are known to laypersons. The full moon in March / April is seen near Spica. Its local name is *Chitra* and the name of the lunar month is *Chaitra*. Each month the star in the direction of the full Moon is different. The fan in the ceiling or a point on the table beneath or a light source elsewhere in the room - can all serve as reference stars to clarify this point.

The Clock as a teaching tool

The other easily available gadget is the mechanical clock which was a household item till the advent of its digital descendants. Still its usage is known to everyone and therefore, it becomes a very handy gadget for explaining various facts as we shall see now.

The discussion begins with the question on the interval between successive overlap of the hands of the clock. At 12:00 hours they overlap; at 6:03 hours the angle between them is 180 degrees. The students are asked - what is the interval after which this configuration repeats. The variety of answers (12 hours, 24 hours etc) leads to a good discussion and finally terminates at the correct answer - about 65 minutes. There are three periodicities here - hour hand of 12 hours, minute hand of 1 hour and the third is the 65 minute interval. A discussion on this quickly reveals that the three are interrelated. Knowledge of any two will fetch the third.

Senior students may be asked to derive the formula - it is pretty simple, and often finds a place in quiz question banks.

$$\frac{1}{t} = \frac{1}{T} - \frac{1}{T'}$$

T and T' are the periodicities of the hands and t is the interval between successive overlaps / constant angle difference.

1. **Sidereal time**
   It is very well known that the meridian transit of a star occurs 4 minutes earlier day by day. One hand represents the sun with a (diurnal) periodicity of 24 hours. The star arrives in advance by 4 minutes every day and will get aligned with the sun after 365.25 days. Putting these numbers into the formula we get the periodicity of the other hand - the duration of the sidereal day as 23 hour 56 minutes. However, we need to give values accurate to 4 or 5 decimal places to get this result. If we use sidereal day = 23.9344696 h, we get the duration of year as 365.2422326

2. **Orbital period of the Moon**
   The month has several definitions - the most popular one may be described as the interval from full moon to full moon (or new moon to new moon). We define the full moon to be represented on the clock by the two hands exactly separated by 180 degrees. One hand is the sun covering 360 degrees in 365.2422 days; the other hand represents the moon. The overlap occurs in 29.530588 days. Plugging these numbers into the formula we get the orbital period of the moon as 27.321661 days. This is the orbital period of the moon with reference to a star. Thus if we see the Moon very close to Aldebaran it will again approach the star after 27.32 days. This demonstration is very useful in explaining the lunar occultations and conjunctions. Here in India, the day is reckoned with the name of the star in conjunction with the moon. Thus the 27 stars attributable to the position of the moon are known to lay persons. They will be able to appreciate the meaning of sidereal month.

3. **Orbital period of planets**
   The hands of the clock now can be extended to understand the motion of planets. If one hand is Mars and the other sun, the 180 degrees position represents the opposition. The interval between successive oppositions can be deduced from patient observations as 780 days. When this is plugged into the formula, we get T' as the orbital period of Mars. Opposition measurements are not relevant for inner planets. Here the successive interval between maximum elongations can be used instead. The students were delighted to know that this method has been in use for more than 2000 years.

4. **Day and night on Mercury**
   Mercury with the orbital and revolution periods as 59 and 88 (earth) days, poses a challenge to imagine the duration of the day and night there. The clock depiction comes in handy there. Imagine yourself on Mercury going round once in 59 days. This represents

This clock depicts the position of the sun and the moon as well as the lunar phase.

one hand of the clock. The sun appears to go round Mercury in 88 days - this is the other hand of the clock. Plugging in the numbers to the formula, you will be wonderstruck. The sun will be at your zenith after 176 days - one "day" is equal to one and half "years"!! This can be used for Venus as well.

The Sun-Moon Clock

Even as we found this clock to be a very useful tool in the classroom, we implemented a large clock in the premises. The "Sun-Moon clock" has 3 m dial and the concealed hands to depict the positions of the sun and the moon in the sky as seen by the observer on Earth (the center of the clock). It shows not only their positions in the sky but the phase of the moon also. This is one example for demonstrating how a classroom discussion with a humble clock made its way to a large science park exhibit.

3D Planetary Tactile Globes for the "Inspiring Stars" Exhibition

Speaker: Amelia Ortiz-Gil, University of Valencia Astronomical Observatory, Spain

Collaborators: J. Burguet-Castell, F. Ballesteros, M.J. Moya, M. Lanzara & M. Pallardó (University of Valencia Astronomical Observatory, Spain), and A. Fernández-Sot (IFCA (UNICAN-CSIC)) [1]

One of the exhibitions created for the 100th anniversary of the IAU in 2019 was "Inspiring Stars", an exhibit with the goal of showcasing examples of inclusion in astronomy. Our contribution to this project was a set of tactile 3D globes of the terrestrial planets and the Moon. They were specially designed to allow persons with visual impairments (BVI) explore by themselves the most relevant features of these celestial bodies. Initially the design and creation of the globes involved complex, but we eventually developed a software capable to produce efficiently 3D digital tactile models from 2D maps. All the models, the software to make them and a couple of activity books are available for downloading at the projectŐs website: "A Touch of the Universe" (https://www.uv.es/astrokit/).

Talk link: https://youtu.be/8icU6LnJ8XA

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In 2019 the International Astronomical Union celebrated its 100th anniversary with activities and exhibitions all around the world. One of those exhibits was "Inspiring Stars", which focused on a range of examples of inclusion in astronomy, from underrepresented groups to people with disabilities.

Our contribution to "Inspiring Stars" was the creation of a set of tactile 3D globes of the terrestrial planets and the Moon (Figure 1). They were specially designed to allow the blind and visually impaired (BVI) to explore by themselves the most relevant features of these celestial bodies. The final models were put to test by BVI astronomers and also users from the general public. The feedback that we gathered allowed us to improve the tactile planetary globes.

[1] This work has been funded by the project PID2019-109592GB-100/AEI/10.13039/501100011033 from the Spanish Ministerio de Ciencia e Innovación - Agencia Estatal de Investigación.

From maps to 3D tactile globes, with Mapelia

Initially, the design and creation of the globes involved several steps of diverse complexity, starting with the edition of the original 2D map to increase the image contrast and smooth out the excess details, in order to obtain a tactile representation of the most important features while getting rid of too much details that make the model confusing when touched for the first time by a blind person. After image editing, as we are astronomers, we used IRAF to create an ascii file from the image in polar coordinates, adding the pixel brightness in each position. Then a 3D rendering software was used to translate the data into a 3D file of the tactile globe [1]. The whole process was long and tedious and prone to introducing errors in the final 3D files. Therefore, we set out to develop a software, called *Mapelia*, that can do the job easily, helping us and also the rest of educators and researchers who could then create their own models [2].

Mapelia is a tool written in Python that uses as input jpg or png files that contain maps (that is, gridded datasets where the value of each pixel is the elevation, brightness or whichever property we wish to render in each case) in any of the following projections: equirectangular, Mercator, central cylindrical, Mollweide or sinusoidal. The output of the program is a 3D file (of polygons like .ply or .stl, or points in space like .asc), that can be visualized and manipulated with programs like MeshLab or Blender. *Mapelia* is accompanied by its "friends" *guapelia*, *pintelia*, *poligoniza*, *stl-split* and *smooth*, which add some other functionalities. In particular, *guapelia* is a GUI to use *Mapelia*, and *pintelia* converts maps into coloured 3D images. All the models, the software to make them and a couple of activity books are available for downloading at the website of the project "A Touch of the Universe" [3].

References:

1. Ortiz-Gil, A. (2018) "3D Tactile Moon", in Proceedings of the EPSC 2018, Berlin (Germany), id.EPSC2018-869

2. Ortiz-Gil, A. & Burguet-Castell, J. (2018) "Mapelia and friends: create 3D models from maps", Journal of Open Source Software -2475-9066, 3, 25, 660-661. doi: 10.21105/joss.00660

3. A Touch of the Universe, https://astrokit.uv.es

The Tactile Universe: Accessible Astrophysics Public Engagement with the Vision Impaired Community

Speaker: Nicolas Bonne, Institute of Cosmology and Gravitation, University of Portsmouth, UK

Astronomy is a topic that engages and inspires a wide range of audiences around the world, but blind and vision impaired people can often find it difficult to engage with the subject due to its very visual nature. The Tactile Universe is an award winning public engagement project based at the University of Portsmouth which is opening up current topics in astrophysics research to blind and vision impaired people through accessible tactile resources based on real data. We will discuss how involving the vision impaired community in the development of these resources has made them truly unique and versatile.

Talk link: https://youtu.be/btRPHqTTYz0

Astronomy is a topic that engages and inspires a wide range of audiences around the world, but blind and vision impaired (BVI) people can often find it difficult to engage with the subject due to its very visual nature. The Tactile Universe is an award-winning public engagement project based at the University of Portsmouth which is opening up current topics in astrophysics research to BVI people through accessible tactile resources based on real data. The project's aim is to demonstrate to this community that astrophysics can be accessible and, in particular, raise the aspirations of young BVI people. The project is led by vision impaired astronomer Nic Bonne.

The core resources of the Tactile Universe are tactile 'height map' images of galaxies, referred to as models. These are created digitally using a custom plug-in created by project technical lead Dr Coleman Krawczyk for the open-source 3D modelling software package Blender. Using monochrome galaxy images, the plug-in maps the image to a 3D surface, where the height of the surface scales directly with the brightness of the corresponding image pixel. The brighter the source image pixel, the higher it is from the base of the model, the darker the pixel, the closer to the base of the model. Physical models can then be produced through techniques like 3D printing and users can feel the shape and features of a galaxy through changes in brightness by running their hand across the model, without the need to see it. An example of an Sloan Digital Sky Survey (SDSS) observation of galaxy Messier 51 (the Whirlpool galaxy) and its corresponding tactile model are shown in Figure 1.

To prototype and develop this basic idea, the Tactile Universe was funded by the South East Physics Network to run a 6-month pilot project in 2016. One of the challenges in developing accessible resources for the BVI community is that every person with a vision impairment is unique, both in terms of the nature and degree of their sight loss, but also in how they have individually adapted to this. To ensure that our tactile images worked for as many different

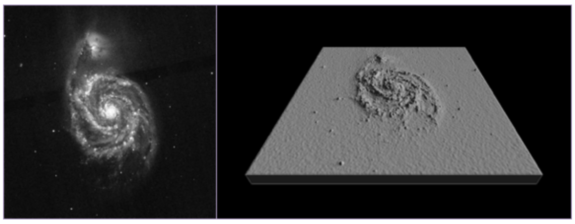

Figure 1: An SDSS image of galaxy Messier 51 (left) and the corresponding tactile model produced using the Tactile Universe's custom Blender plug-in (right). The height of any point on the surface of the model scales with the brightness of the image's pixels.

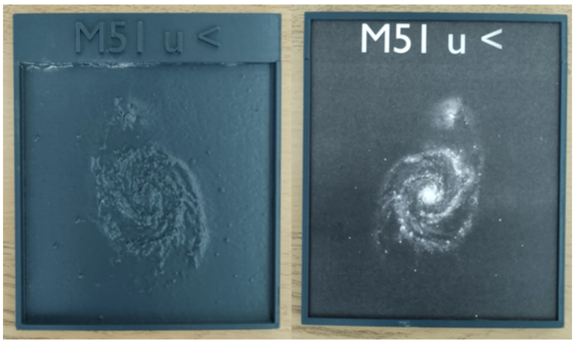

Figure 2: 3D printed tactile models of galaxy Messier 51 from the front and the back. On the front (left) the models include the tactile surface, a tactile name plate for easy identification, as well as a raised border around the edge of the model which is the height of the brightest point in that image. The back of the model (right) has a mirrored print-out of the image used to make the model, so that users with some vision can look at this while touching the corresponding tactile features on the front.

people as possible, it was crucial to involve the BVI community in further developing our resources. To facilitate this, we tested our tactile model concept with a BVI support group based in Portsmouth, so that we could get their feedback.

Initially, we produced a series of tactile images of galaxies with a variety of tactile heights (the distance between the dimmest and brightest point on the model) ranging from 1mm to 5mm. The consensus from the group was that a tactile height of 3mm was the best option, as more gradual changes in brightness could still be perceived, and abrupt changes in brightness (as in the case of foreground stars) were not so sharp as to be unpleasant to touch. We also produced models of different sizes. Models roughly the size of a postcard were the preferred option, as these were easy to handle, and were not so large that participants got lost as they felt their way across them.

Members of the support group also provided suggestions that allowed us to improve the models in other ways. To allow users with some vision to use their tactile and visual senses, we added a print-out of the original galaxy image used to make the model to the model's back face, mirrored so that it would directly correspond to the tactile features on the front. Participants also wanted a way to judge how high or 'bright' any part of the model was. The solution was to add a raised reference border around the tactile image which has the same height as the brightest tactile feature. Users can easily compare this to whichever part of the model they are exploring. Lastly, to allow users to quickly identify which model they were handling, we developed tactile name plates which sit at the 'top' of each tactile image. These name plates are particularly useful when jumping between sets of these models where we use multiple versions of the same galaxy in different wavelengths. The 3D printed models with all of these features can be seen in Figure 2.

During these test sessions we quickly realised the importance of appropriate descriptions and explanations to support users in understanding these models. Working with this group, we were able to find analogies and comparisons that worked. For example, using rugby balls and CD's to describe the 3D shapes of elliptical and spiral galaxies, and demonstrate how we perceive galaxies from different angles; linking the idea of colour in a galaxy to the temperature of its stars; comparing the structure of a galaxy to a rain cloud etc.

Beyond this pilot, the Tactile Universe received funding from the Science and Technology Facilities Council to expand its reach and to further develop its resources for applications to a classroom setting. Working with BVI students from local primary and secondary schools we have developed a series of lesson plans that incorporate models of a variety of distinct galaxy types, alongside language, descriptions and analogies that are accessible to BVI participants, but can also benefit sighted classmates. These workshops begin with local scales and sizes in our solar system, build up to Milky Way scales, and finally discuss galaxies in their many different forms.

To allow anybody to access these resources (3D printable models, Blender plug-in, lesson plans and scripts for primary and secondary school students) we have shared them online for free. They can be downloaded from our project website (www.tactileuniverse.org).

Engaging with the BVI community throughout this project has been a sometimes challenging but ultimately rewarding experience. By working with the BVI community from the beginning and by listening to their feedback and suggestions, our resources are more versatile, and how we use them to engage the community has been improved in ways that would not have been possible without their input.

Teaching with Astronomy Exhibits

Presenter: B. R. Sitaram, Zeal Education, Ahmedabad, India

In this poster my collection of Astronomy teaching aids is presented. These include the sunrise locator, sunrise timer, sub-solar point model, seasons models, moon phase calculator, constellation charts, guess the constellation, etc. All these are actual hands-on models, not computer apps and can be easily assembled by students. As an example, the sunrise locator and timer shows you the location and time of sunrise/set at any latitude on any day of the year.

Poster link: https://astro4edu.org/siw/p77

These are some Astronomy teaching aids that I have designed (https://www.teacherspayteachers.com/Store/Sitaram-Bettadpur). All these are actual hands-on models. We regularly conduct workshops where students are sent kits in advance and they assemble and learn how to use them. These, and similar models in science and maths, have proved to be very popular with students. The models discussed are:

1. Sunrise Timer: Shows the time of sunrise on any date at any location: Useful in explaining seasons (duration of sunshine).

2. Sunrise Locator: Shows the location of sunrise on any date at any location. Useful in explaining seasons (angle at which sunshine strikes ground).

3. Sub-solar point model: Shows the subsolar point (point on earth's surface where the sun is at the zenith) at the instant of observation. Useful for showing apparent north-south movement of the Sun.

4. Moon phase calculator: Finds the phase of the moon on a specific date. Important for sky-watch planning, timings of tide and for festivals based on the lunar calendar.

5. Ephemeris: Shows celestial longitude of Sun, Moon and planets over a calendar year. Shows difference in speed of movement across sky, possibility of seeing a planet on a particular night, phase of the moon, retrograde and prograde motions.

6. Solar System Distances Strip: A long (5 m) strip that concertina folds into a pocket map showing the distances between the sun and planets. Also shows the Sun to scale, showing how vast the system is even compared to the Sun.

7. Constellation cards: A jig-saw puzzle with constellations represented in three forms: only stars, stars with connecting lines and with imaginary figures superimposed.

Starry Starry Night

Presenter: Tan Jyh Harng, Singapore Science Centre, Singapore, Malaysia

Constellations are excellent stepping stones for young children when they begin learning astronomy. It is common pedagogy involving storytelling when it comes to learning. Constellations have rich stories behind them which makes them easy to teach children. From there, it is easy to link up to other areas as well, such as the names of the major stars and also seasons as well. In this exhibit and activity, a star chart is made with sticks representing as stars and rubber bands as the imaginary connecting constellation lines. Children can practice remembering the constellations by 'connecting the lines' using the rubber bands.

Poster link: `https://astro4edu.org/siw/p21`

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It is common pedagogy involving storytelling in early childhood education. Hence, constellations are suitable for young children due to the rich mythologies involved. Using these stories, other topics of Astronomy can be introduced as well. In this exhibit, a star chart is made with sticks representing stars and rubber bands as the imaginary connecting constellation lines. Children can practice remembering the constellations by 'connecting the lines' using the rubber bands. Located in Science Centre Singapore, KidsSTOP™ is a dedicated Children's Science Centre. One of the interactive exhibit booths that KidsSTOP™ has is the Starry Starry Night. This booth uses plastic tubes of various diameter to represent the stars of the night sky. Children can make use of the rubber bands to connect the plastic tube together to form the imaginary lines of the constellation.

With the common constellations already traced out, children can follow it to 'connect' the stars. This process can help them familiarise with the shape of the constellation. Alternatively, children may also use their own creativity to connect the plastic tubes to trace out their own constellation or asterisms. Educators may also use the opportunity to teach of the term asterisms, commonly identified patterns of stars that are not a constellation. To enhance the visual appeal of the exhibit, fluorescent materials are used in the plastic tubes. Under black light, the 'stars' can appear to glow.

A challenge of the Starry Starry Night exhibit is the height of the wall. As the star map is relatively tall, younger children may have issues reaching the 'higher' stars. Use of a stool or making the star map wall smaller are possible mitigation methods. Such interactive exhibit can also be made into smaller-scale hands-on activity. For example, using toothpicks on a foam/cork board to create a star map and thereafter using rubber bands or strings to trace out the constellations. For more information about Science Centre Singapore and KidsSTOP™ , visit `https://www.science.edu.sg/`.

One entry point of KidsSTOP™.

Starry Starry Night exhibit.

An example of a self-created asterism in the constellation of Orion.

Discussion summary

In the first discussion session, we received a certain number of questions addressed to Nicolas Bonne, concerning the 3D Models he introduced in his presentation, which he uses for Astronomy teaching and outreach purposes, mainly aimed at the visually-impaired, blind pupils, and the general public. In particular, he was questioned about the size of the models, the type of 3D printers used, the difficulties he experienced in people's feedback, and the lessons learned. Nicolas answered promptly, with indications about the size of the models, the link for downloading the globes' files, and the models of 3D printers used by his team. He also described the mixed reactions of children and the general public, which could help decide possible modifications of the models. We then asked Amelia Ortiz-Gil whether her team carried the 3D globes in the school's classrooms, and whether she was thinking of producing other globes and other exhibitions after the "Inspiring Stars" exhibit. Amelia confirmed that the globes had been used in Spanish schools, whereas the exhibition was travelling in other European countries, Italy in particular. As hosts, we then asked Wolfgang Wieser how he had adapted his workshops to a virtual format during the pandemic, the challenges he faced, and whether his team had produced a virtual tour of the large and interesting ESO Supernova exhibition halls. Wolfgang confirmed that online workshops had been prepared and widely used during the lockdown, and a lengthy virtual tour had been produced by his colleagues. Finally, we asked Farprakay Jiarakoopt whether they organized teacher training courses, and indeed we discovered that NARIT offers courses at various levels and focused on different topics of Astronomy and Astrophysics.

In the second discussion session, we started by asking Rick Tonello to describe his experiences travelling with a telescope for stargazing activities in various villages of Western Australia. Rick described his "adventures in the bush" and the enthusiasm of the public during stargazing nights. Since he was also asked about the fabric used for his space simulator and the issues faced with the public, he gave details about Spandex and funny anecdotes on people's questions and reactions. Nicolas was asked about the possibility of creative labs for visually-impaired pupils, and he said it would be a good idea and they would think about it. Wolfgang was asked about the role of interactivity in his workshops, and he confirmed this was indeed the core of such teaching activities. B.S. Shylaja was asked about the age-group of pupils that her classes are aimed at. She confirmed there were labs aiming at different age groups. Amelia was asked about the best possible feedback she had received from the public, and she described very moving and rewarding episodes. Finally, on request, we allowed Jan Sermeus, from KU Leuven University Planetarium, Belgium, to announce the survey organized by his team about planetarium activities and needs in various countries.

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