

The background features a central dark blue circle with a lighter blue ring around it. This is surrounded by several concentric dashed light blue lines representing orbits. There are several small grey dots representing stars and three larger blue spheres representing planets or moons. One planet has a ring system, similar to Saturn. The overall theme is astronomy and space exploration.

Proceedings for the

**5th Shaw-IAU Workshop
on Astronomy for Education**

**Special Topics:
Astronomy Beyond the Classroom
Planetary Climate**

29th November – 1st December, 2023



Compiled & Edited by:

Samantha Brown-Sevilla, Eduardo Penteadó, Sophie Bartlett, Niall Deacon, Tshiamiso Makwela, Tilen Zupan, Rebecca Sanderson, and Vivek Reddy Pininti.

The following is a collection of summaries from the 5th Shaw-IAU workshop on Astronomy for Education held 29th November - 1st December, 2023 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/5th-shaw-iau-workshop/>

The IAU Office of Astronomy for Education (OAE) is hosted at Haus der Astronomie (HdA), managed by the Max Planck Institute for Astronomy. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. HdA's hosting the OAE was made possible through the support of the German foundations Klaus Tschira Stiftung and Carl-Zeiss-Stiftung. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

The OAE is supported by a growing network of OAE Centers and OAE Nodes, collaborating to lead global projects developed within the network. The OAE Centers and Nodes are: the OAE Center China-Nanjing, hosted by the Beijing Planetarium (BJP); the OAE Center Cyprus, hosted by Cyprus Space Exploration Organization (CSEO); the OAE Center Egypt, hosted by the National Research Institute of Astronomy and Geophysics (NRIAG); the OAE Center India, hosted by the Inter-University Centre for Astronomy and Astrophysics (IUCAA); the OAE Center Italy, hosted by the National Institute for Astrophysics (INAF); the OAE Node Republic of Korea, hosted by the Korean Astronomical Society (KAS); OAE Node France at CY Cergy Paris University hosted by CY Cergy Paris University; and the OAE Node Nepal, hosted by the Nepal Astronomical Society (NASO).



5th Shaw-IAU Workshop on Astronomy for Education

In astronomy education, there is always something new to learn. Have our education activities moved in a new direction, and you would benefit from learning from others who have spent more time in that new corner of our field? Is there an aspect of astronomy education you have long been interested in, but never got around looking into in more depth? And then there is always the benefit of looking around in your own field of specialisation to see how others do it – and if you are lucky, take something away that you can use.

Our Shaw-IAU Workshops on astronomy are meant to provide astronomy educators — teachers, astronomers, everybody — with opportunities for this kind of learning. This is the fourth online workshop, and the fifth overall in our series of Shaw-IAU Workshops funded by the Shaw Prize Foundation. Going by participants' feedback from the previous workshops, we believe our workshop has now evolved into a format that meets the needs of our community. Sessions on how astronomy education works in practice, both in primary and secondary schools, or on evaluation and astronomy research, or on teaching methods and tools, are so close to the heart of what we do that we plan to have them in every future edition of this workshop.

Part of our concept are that each workshop now has two special topics. One is about the practice of astronomy education. Here, this years special topic was “astronomy education beyond the classroom,” covering astronomy education in museums, planetariums, science camps and other non-school settings. We also included projects that bring something unusual *into* classrooms, such as “Skype a Scientist.” Then there is our special science topic, meant to bring educators up to speed in a particular area of astronomy. This year, we chose “planetary climate,” both for the central challenge of climate change humans on Earth are facing at this time and for the exciting recent results about exoplanet atmospheres.

For astroEDU, our review for peer-reviewed classroom activities, there were two sessions introducing participants to the platform, and exploring with them how their educational activities could be turned into astroEDU online resources. There were also community discussions in Arabic, Hebrew, Portuguese, Romanian and Spanish. We realise that English as the common language of our workshop makes things difficult for some participants, and community discussions in languages other than English are an integral part of our concept.

Making this Shaw-IAU Workshop a reality was a group effort. A big “Thank you!” goes out to the individuals who did the work, whose names you can find on p. 9, and of course to the Shaw Prize Foundation for their generous funding. Want more? We just set the dates for the next edition: 12 to 14 November, 2024. In the meantime, do stay in touch. 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, Facebook and Bluesky, as @astro4edu.

Markus Pössel
Director, IAU Office of Astronomy for Education
Heidelberg, January 2024

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Organising Committees

Local Organising Committee:

Sophie Bartlett, Samantha Brown-Sevilla, Niall Deacon, Tshiamiso Makwela, Eduardo Penteadó, Vivek Reddy Pininti, Markus Pössel, Gwen Sanderson, Rebecca Sanderson, Tilen Zupan.

Scientific Advisory Committee:

Ali Al-Azzary, Tariq Al-Khatib, Dalal Al-Lala, Maryam Al-Qassab, Sophie Bartlett, Abdul Latif Bendhou, Sandra Benitez, Samantha Brown-Sevilla, Felicia Călmuc, Faustine Cantalloube, Nicolas B. Cowan, Niall Deacon, Rosa Doran, Federica Duras, Silvia Galano, Beatriz García, Livia Giacomini, Edward Gomez, Joanna Holt, Tshiamiso Makwela, Giulio Mazzolo, Shahrzad Mirsoltani, Thomson Mucavela, Elisabeta Ana Naghi, Breezy Ocaña Flaquer, Cláudio Paulo, Eduardo Penteadó, Ángela Perez, Julia Plummer, Markus Pössel, Sarah Roberts, Somaya Saad, Saeed Salimpour, Gwen Sanderson, Ahmed Shaalan, Shylaja B S, Exodus CL Sit, Juan Ángel Vaquerizo, Ayelet Weizman, Hila Yeshurun.



Astronomy Education in Practice

Session organisers: Sophie Bartlett (OAE Heidelberg), Sarah Roberts (Swansea University, Faulkes Telescope Project, Wales), Silvia Galano (Università Federico II, Italy), Shahrzad Mirsoltani (Director of the Kargahe Setare Project, Iran)

SESSION OVERVIEW

This session focused on astronomy education activities in classroom settings. The presentations provided examples of classroom practices that had worked well and described how such activities were developed. Speakers discussed both the context of teaching astronomy as its own subject, as well as part of other subjects. Evidence of classroom practice was presented for both primary/elementary and secondary/high school settings.



Astronomy to Reduce School Segregation: Lessons Learned from Participation in the Magnet Program

Speaker: Jorge Rivero Gonzalez, Institute of Space Sciences (ICE-CSIC), Spain

Collaborators: Alba Calejero García, Ángel Elbaz, Guillem Anglada-Escué, Clara Dehman, Albert Elias López, George Ferentz, Lluís Galbany, Josep Miquel Girart, Abubakr Ibrahim, Daniel Iñiguez, Cristina Jiménez, Simranpreet Kaur, Maria Kopsacheili, Alessio Marino, Álvaro Sánchez Monge, Juan Carlos Morales, Tomas Müller Bravo, Miquel Nofrarias, Celsa Pardo, Carlos Rodríguez, Michele Ronchi, Clàudia Soriano, Daniele Viganó; all affiliated to the Institute of Space Sciences (ICE-CSIC)

School segregation is a growing problem throughout Europe that tends to create schools with a very high socioeconomic complexity. We present our experience within the Magnet program, where the Institute of Space Sciences collaborates in the 2021-2025 period with a school in Igualada (Spain). Advised by an expert in didactics, we have co-created with teachers and implemented inquiry-based astronomy activities for 3 to 11 year old students. The goal is to provide the school with added pedagogical and educational value, which can attract local families, in order to balance the demographics of the student body and promote inclusion in current and future society. In this talk, we will present the activities organized during the first half of the program, plans for the future, and lessons learnt.



School segregation is a growing problem throughout Europe that tends to create schools with very high socioeconomic complexity [1]. Although this is not a new phenomenon, educational sciences have changed significantly in recent decades, and the inclusion of diversity is considered a pillar and an asset.

In this communication, we present the experience of the Institute of Space Sciences (ICE-CSIC) within the Magnet programme [2], a program led by the Bofill Foundation inspired by the magnet school model in the United States of America. Within the Magnet program, the Institute of Space Sciences (ICE-CSIC) collaborates, in the period 2021-2025, with the Gabriel Castellà School — an Early Childhood and Primary Education school with students with integration difficulties — on the outskirts of the town of Igualada, in the province of Barcelona. Together with the teaching staff and advised by a teaching expert, we have co-created different interdisciplinary



Figure 1: ICE-CSIC researchers and students discuss about how the rainbow is formed. Credits: ICE-CSIC.

activities and projects related to space science and astronomy, suitable for students from 3 to 12 years old and their families.

The main objective of the Magnet Alliance is to provide the school with added pedagogical and educational value, which can attract local families, in order to balance the demographics of the students and promote inclusion in current and future society. For this purpose, both the school and the research center work with an educator who can guide them on their journey to turn the center into a reference in their territory.

This alliance is developed in 5 years. In the first one, the first contacts between the school and the research centre are done and the foundations of the project are laid. During the second year is when the alliance really begins to work and there are the first interactions with children and teachers. However, it is during the third and fourth years that the main programs are developed. The focus of the final year is on the consolidation of the programs.

An important aspect of ICE-CSIC's involvement is focused on supporting the learning cycle of students. Teachers from the different classes start working on a topic with students through an initial question — that they first discuss with us — which can spark curiosity in the students, for example, "How are stars born?" Then the students come up with their own hypotheses, posing more questions that they discuss with the teachers and evaluate their hypotheses, discarding some of them. They usually depict with drawings their ideas as well.

At this stage, ICE-CSIC researchers have another interaction with the teachers to discuss what should be the next steps, and we start to plan a visit of our researchers to the school. During these visits, students present to the researchers what they have been working on and open a discussion with them. ICE-CSIC researcher also organise inquiry-based hands-on activities about the topic to get deeper into the subject. After that, students communicate to their classmates and families what they have learned, and usually, other questions appear, making them realise how the scientific method works.

Another of the activities carried out in the Magnet Alliance are teacher trainings about astronomical topics, both presenting theoretical concepts and showing examples of activities to bring these topics in the classroom. Other activities worth highlighting are the participation



Figure 2: Student presenting to an ICE-CSIC researcher different ideas developed by students to explain how stars are born. Credits: ICE-CSIC.

in special events open to the entire city of Igualada, such as the observation of the UN International Women and Girls in Science Day on February 11th, with the engagement of ICE-CSIC female researchers in special activities for the school or during the European Researchers' Night celebrated during the last Friday of September across Europe, where ICE-CSIC was present in the activities organised by the school with a stand featuring hands-on activities as well as solar and night-time telescope observations.

Impact

Even though it is still early on the project to evaluate the achievement of its main goal, namely, decreasing the level of segregation in the school, we are already able to measure the benefits the project is bringing to both the school and our institution.

On one hand the project has a tremendous impact on the school's teachers. At the end of each academic course, an evaluation report is prepared by the educator that supports both the school and the research centre. It is interesting to see the impact on the educational staff from one course to another. For example, at the end of the academic course 2022-2023 almost 76% of teachers indicate that they use the knowledge provided by the research centre in their daily work, in comparison with 47% of them the previous year. Another finding to highlight is how the majority of teachers (94%) create learning situations that require the use of inquiry learning, which is almost three times larger with respect to the previous academic year (26%).

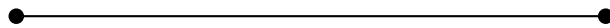
On the other hand, for ICE-CSIC, the project is also very rewarding because it has served to channel the participation of our research staff in educational activities structured by the institute's Communication and Outreach Office.

Finally, the Magnet activities also provide students with skills such as working in a team, asking questions, experimenting and evaluating results, in principal, fostering critical thinking, which are skills that will be vital for their entire life.

It is because of these types of impacts that the Magnet Alliance is very important for ICE-CSIC because it makes us keep in mind that in our journey to unravel the mysteries of the universe we cannot leave anyone behind.

References:

- [1] Fighting school segregation in Europe through inclusive education. Council of Europe Commissioner for Human Rights, 2017
- [2] Les aliances Magnet: innovació per combatre la segregació escolar. Tarabini, A. et al. (2018). Fundació Jaume Bofill, 2018



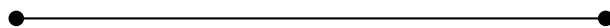
Using Astronomy to Tackle the Consequences of COVID in the Classroom

Speaker: Emma Wride, AstroCymru, UK

One in three children in Wales live in poverty and the recent pandemic has exaggerated many issues these children experience in education. Teachers' feedback has shown that, after this disruption, pupils benefit more from 'hands-on' learning. They need engaging, authentic experiences. Aspirations more so now than ever need to be raised in young people and fostering the belief they can achieve is crucial. This talk will share experiences of the consequences of COVID in the classroom and how Astronomy-related workshops delivered by Astro Cymru are helping to tackle these issues.



Talk link: <https://youtu.be/mWiWa0JWPko>



The Musical Universe: Introducing Interdisciplinary Astronomy-Music Workshops into Primary Schools

Speaker: Anne-Marie Wijmans, School of Physics and Astronomy, University of St Andrews, UK

Collaborators: Ellen Thomson, Laidlaw Music Centre, University of St Andrews; Paula Miles, School of Psychology and Neuroscience, University of St Andrews

School workshops can be an excellent way to introduce young pupils to all kinds of academic topics, and inspire them to learn. Ideally, a school workshop contains several elements to allow the pupils to approach the topic from different angles and reinforce their learning.

We developed a pilot of 3 workshops combining astronomy and musical composition, with both disciplines complementing each other. We delivered these workshops in three different P5 (9-10 year olds) classrooms in Scotland. We evaluated the workshops by interviewing the class room teachers before, immediately after, and several months after the workshops. We find that the workshops had long-term positive impacts on both teachers and pupils, which we will report on in this talk.



Talk link: https://youtu.be/0c2mM0Bw_vA

For several years now, we have been delivering workshops to children in primary schools, where we combine astronomy and music. Often these workshops are structured so that we first introduce astronomical concepts, and then use music to explore these concepts further –through listening, composing, or performing. We use this interdisciplinary approach so that the children will have multiple angles to engage with the material, depending on their own individual interests.

With the Musical Universe we want to investigate whether these interdisciplinary astronomy-music workshops have a long-term impact in the classroom. We are interested in changes in the classroom environment, such as the confidence, knowledge, and skills of the pupils, as well as their attitude towards collaborative group work. We also want to find out whether the teachers show any changes in their attitude towards teaching music and science, such as their confidence and enthusiasm for teaching these subjects and developing new activities. We measure possible impact through pupil questionnaires and teacher interviews. The teachers are interviewed before the workshops, immediately after the workshops, and also three months later to record

	Astronomy	Music
Workshop 1	Our Solar System	Structure of piece and musical components
	Planets - properties	Section A composition
	Orbits - speed/distance	Rhythmical riffs (science vocabulary) 2 speeds Planet property representation
Workshop 2	Stars	Section B composition
	Temperature/colour	Star type, musical representation
	Lifespan (nebula/supernova)	Revise section A elements
Workshop 3	Components of the Milky Way	Revise and refine sections of piece
	Geography of solar system and star placement/habitats	Create final ABA structure Record pieces

Table 1: Workshop structure, indicating the astronomy and musical concepts addressed in each workshop.

any potential longer-term impact. The pupils fill out their questionnaires immediately after the workshops.

We designed a series of three workshops that we delivered in three different classrooms. These classrooms were located in primary schools in Scotland, and aimed at 9-10 year old pupils (P5 in the Scottish school system). The workshops were designed to align with the Scottish Curriculum for Excellence¹, and we identified a few key areas within the curriculum related to the Sciences and Expressive Arts. These were SCN 2-06a (solar system), SCN 2-20a (topical science), EXA 2-17a (experimenting with sounds, pitch, melody, rhythm, timbre and dynamics), EXA 2-18a (expressing ideas through musical activities), and EXA 2-19a (listening and constructive commenting).

Table 1 shows the structure and content of each workshop. We started each workshop with a plenary introduction and warm-up, followed by a 30-minute interactive astronomy lecture. This was then followed by a composition workshop. We had asked the teacher to create working groups of 4-6 pupils, and these groups each worked on their own musical composition. Half of the groups worked on their compositions immediately after the astronomy lecture, while the other half of the groups took part in a Question and Answer (Q&A) session on astronomy. After 30 minutes, these groups swapped over. We incorporated a Q&A session to allow the pupils to ask any astronomy questions they could not ask during the lecture because of time, and to explore additional astronomy topics. In addition, having only half the classroom working on their musical composition also allowed us to put a bit more distance between different groups

¹<https://education.gov.scot/curriculum-for-excellence/curriculum-for-excellence-documents/experiences-and-outcomes/>

to minimize interference (sound levels), and this was easier to do in half-empty classrooms. The groups working on their musical compositions were supported by a workshop leader, as well as students from the University of St Andrews.

The pupils and teachers were very positive about the workshops, and the pupils were highly engaged both in the astronomy and music sessions. The format for the workshops seemed to work well within all participating classrooms, but we did note that the groups were able to work better on their composition if they were placed in separate locations (e.g., extra room, canteen, or corridor).

The analysis of the pupils' questionnaires and teacher interviews is still on-going, but preliminary outcomes from the interviews indicate that the workshops did have a longer-term impact on both the teachers and the pupils. Teachers reported that they gained a new perspective on delivering new content, and that they were planning to use similar structures as we used in the workshop, to support learning of new concepts with music. They did voice concerns on having suitable spaces to do this, and having sufficient support. We are planning to follow-up with these teachers later in the year to find out if they indeed implemented structures from the workshop as planned, and if not, what prevented them from doing so.

Overall, we conclude that the Musical Universe interdisciplinary workshops have a positive, long-term impact on the classroom. We have more workshops planned to further investigate this impact, and to work with teachers to increase the impact that interdisciplinary science and music teaching can have.



Astronomy@MyBackPack

Speaker: Rosa Doran, NUCLIO - Núcleo Interativo de Astronomia e Inovação em Educação, Portugal

This presentation has two main objectives: to present a new project called Astronomy@MyBackPack and a methodology to deliver curriculum content while using the astronomy-related activities contained in the backpack. The backpack contains several hands-on activities, digital simulations, and a micro:bit kit, and it will be a continuously updated and upgraded kit.



Talk link: <https://youtu.be/dV4Hn4HNaTk>

During the presentation, the importance of engaging the audience through interactive and thought-provoking activities is emphasized, sparking the curiosity of the audience, promoting discussions and collaborative exploration of possible solutions to the various riddles presented. This methodology is adequate for educators while involving students in new learning episodes but also for trainers that will prepare educators to use the kit.

The Astronomy@MyBackPack contains materials that will enable educators to address several astronomical concepts such as, for instance, the phases of the Moon, solar eclipses, distance and size scales in the Solar System and more. It also contains tutorials on the use of digital tools such as, for instance, Stellarium, Gennially, worldwide telescope, etc. Suggestions for the use of the micro bit and associated sensors will also be part of the content.

Models for the involvement of the audience and how to facilitate their understanding and co-create learning experiences are also presented in this talk.

As part of the proposed methodology, the significance of guiding the audience to collect and analyze data, reach conclusions, and present their findings, is also highlighted.

The presentation also includes the use of online facilities that can greatly help educators to build engaging scenarios, including AI opportunities, that in conjunction with the material of the backpack, can initiate a deeper learning experience for the students involved in its use.

Part of the success of the strategy is also to make sure the specific needs of educators and learners are properly addressed. The importance of inclusive environments and the adoption of universal design of the various components is also something considered for the development of the various kits.

Users of the Astronomy@MyBackPack will be invited to provide feedback on its content and associated instructions, to keep an open dialogue with its creators in order to guarantee its successful implementation in diverse environments with the freedom to properly localize its contents, and to be co-creators of future versions of this kit.



The Tactile Universe: Accessible Astrophysics Public Engagement with the Vision Impaired Community

Speaker: Nicolas Bonne, Institute of Cosmology and Gravitation, University of Portsmouth, UK

Collaborators: Coleman Krawczyk, Jen Gupta & Laura Nuttall, Institute of Cosmology and Gravitation, University of Portsmouth

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 tactile resources based on real data. Below, we'll showcase our core resources — 3D printed tactile images of galaxies — and share how involving the vision impaired community in the development and delivery of the project has shaped the project and these resources in unique ways. We'll also discuss how these resources can be used in classroom settings to engage and inspire young people with vision impairments.



Talk link: <https://youtu.be/afxGnwx2VAI>



Motivation: Astronomy is traditionally perceived to be a very visual science. Everything from how we do our research (a heavy reliance on visual data and images) to how we communicate astronomy to the public (often using stunning and inspiring images of space). For this reason, people who are blind or vision-impaired (VI) can often find it challenging to fully engage with astronomy as a hobby, interest, or as a profession.

In 2016, a small group of astronomers and public engagement professionals based at the University of Portsmouth set out to address this issue by creating the Tactile Universe project. Led by vision-impaired astronomer Dr. Nic Bonne, the project's main goals are to: (1) Show young people with vision impairments that STEM subjects can be for them and raise their aspirations, (2) Work with the BVI community to develop and share accessible resources for learning and research, and (3) Help and inspire others to communicate their science in more accessible ways.

Core resources: The core resource of the Tactile Universe project are 3D surfaces, similar to 'height maps' created from telescope images of galaxies, sourced from the Sloan Digital Sky Survey (SDSS) DR13 data release (Albaret et al., 2017). Created using a custom plug-in for 3D modelling software, Blender (www.blender.org), the models map the brightness of the pixels in the image into corresponding tactile features. In this way brighter pixels represent more prominent tactile features and dimmer pixels are closer to the base of the model. In Figure 1, we show an example of how the software maps an image to the 3D surface.

By turning these models into physical objects (using techniques like 3D printing), users can run their fingers and hands over the models to feel the shapes of the galaxy and get a sense of how the brightness changes across each image without necessarily needing to see the image.

Co-creation has been a major part of this project from the very beginning, and by working closely with a number of blind and vision-impaired people during the development of these resources, we have been able to make them more versatile. At a basic level, this feedback allowed us to choose the best height of the tactile features (in this case 3mm) and the best size for the surfaces themselves (each model is roughly the size of a postcard). We were also able to include less obvious improvements. So that users can work out how bright any part of the surface is, each model has a raised border, which is as high as the highest tactile feature. To accommodate users with some usable vision, we also included a mirrored version of the image used to create the tactile surface on the reverse side of the model. Users can then look at this image while feeling the corresponding tactile features on the other side. This allows users to utilize whichever combination of visual and tactile is most useful to them. Images of the front and back sides of final 3D printed models can be seen in Figure 2.

As well as making the models more accessible, working with members of the VI community helped us develop the most impactful and accessible language to use when describing these images and the science we wanted to communicate. Analogies had to be relatable (e.g., linking to things that people were more likely to have touched or heard, rather than seen). Take, for example, a discussion about a spiral galaxy. Though it looks like a whirlpool, this isn't something that can be touched, so finding another analogy for a spiral becomes important.

Schools engagement: With these resources at their core, we've created a number of workshops which have been successfully delivered to students in upper primary school and lower secondary

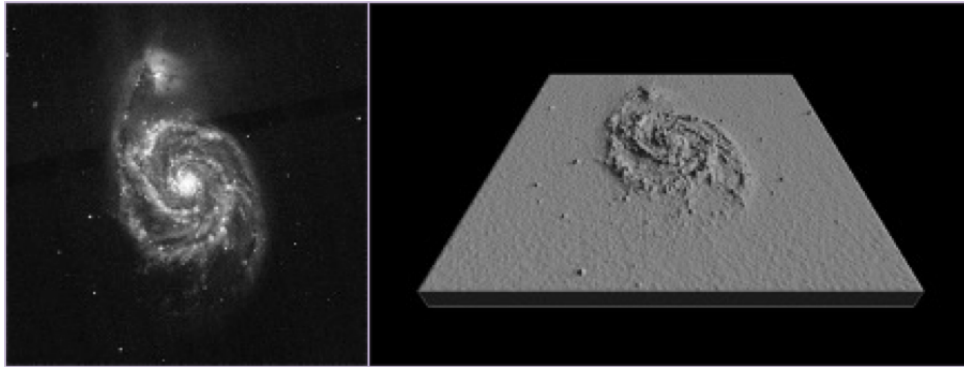


Figure 1: A telescope image of galaxy M51 from SDSS DR13 (left) and a tactile surface produced in 3D modelling software Blender which shows a 'height-map' tracing the brightness of the image pixels.

school in UK classrooms.

For primary school students, we start off with a workshop focused on the Solar System. This allows us to build up concepts around size and scale. We rely on more basic resources here, talking about the comparable sizes of the planets and the Sun using common objects like peppercorns, tennis balls and beach balls. Students then map out the Solar System on a long strip of paper with tactile stickers placed to represent scale separations between each planet. In our second primary school workshop, we build our sense of scale to talk about our place in our own Milky Way galaxy. We introduce tactile images of the night sky, a tactile image of our Milky Way viewed (inside out) from the Earth and get students to build their own Milky Way using a CD and some Play-Doh. We then introduce other more distant galaxies using a set of 10 tactile images of galaxies, each with unique shapes and features. To finish off the workshop., students are asked to come up with their own classification scheme for the galaxies in their sample.

For secondary school students, we deliver a modified version of the galaxies workshop where we go into more detail about some of the physics going on inside and around the galaxies to give them their particular shapes. We also introduce concepts around colour (linked to ideas around stellar populations like hot young blue stars and old, cold red stars) where we include images of each galaxy which highlight bluer or redder wavelengths of light and highlight which parts of particular galaxies contain these different types of stars.

In terms of delivery, we've experienced two main modes and both have their advantages and disadvantages. Whenever possible, we've tried to deliver these workshops to full classrooms. Because many of the VI students in the UK are embedded in mainstream classrooms (where they may be the only child with a vision impairment), by involving their classmates and getting everybody working with the same resources at the same time, we're able to give every student the same experience. VI students have reported feeling more included in these classes and some of their sighted peers have gained a better understanding of issues around accessibility. The disadvantages of this mode of delivery are that more physical resources are needed to run these sessions well, and students are less likely to ask questions.

In instances where we've worked exclusively with individuals or smaller number of VI pupils, it has been easier to build trust and open up clear communication with these students. These sessions can feel more personal for students, making them more likely to ask questions and we

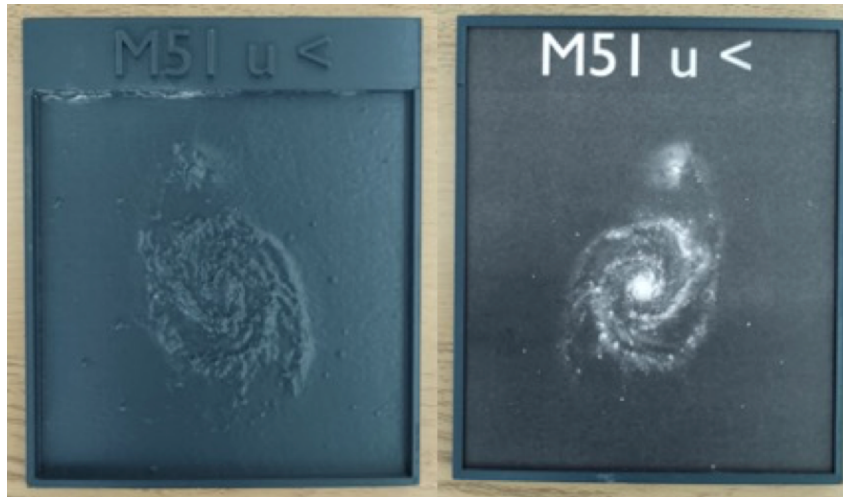


Figure 2: An example of a 3D printed version of one of our tactile images. The front of the model (left) has the tactile surface, a tactile name plate, and a raised border around the edge to help users calibrate what they are feeling. On the back (right) of each model, we've attached the image used to make the model which mirrors the tactile features on the opposite side.

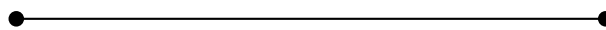
can focus more easily on misconceptions or misunderstandings if they arise.

In both of these scenarios, we make an effort to give students agency, letting their exploration of the resources guide discussion and empowering them to make discoveries on their own.

Conclusion: To find out more about Tactile Universe, download and 3D print our resources, make your own 3D surfaces using our software plug-in, or access lesson plans and scripts for our workshops, please go to www.tactileuniverse.org. Everything is free and we're delighted to share.

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Training Novae Hunters: Using Light Curves of Novae for Mathematics Learning in the School Classroom

Speaker: Ignacia Benito-Cisterna, Center for Interdisciplinary Research in Astrophysics and Space Science, San Ignacio El Bosque School, Chile

Collaborators: Rubén Montecinos & Carla Hernández, Physics Department, Universidad de Santiago de Chile (USACH), Center for Interdisciplinary Research in Astrophysics and Space Science (CIRAS), Millennium Nucleus on Young Exoplanets and their Moons (YEMS)

The pedagogical team of the Center for Interdisciplinary Research in Astrophysics and Space science (CIRAS) aims to enhance astrophysics learning using astronomical data. We develop educational activities aligned with the high school curriculum in Chile, incorporating cutting-edge astrophysics research to motivate student learning. Using time-resolved photometric data from the LCO Global Sky Partners project, we construct light curves of recent nova explosions. These data are used to create comprehensive teaching sequences on topics like growth and decay functions in mathematics at the high school level. By bridging the gap between scientific research and the classroom, we contribute to a more engaging learning experience.



Talk link: <https://youtu.be/cpcuEJLih1Q>

Introduction

Chile is a geographically privileged country for astronomical observation and research in the world. However, there is a lack of astronomy content taught at the school level, a situation that is also observed in other OECD member countries.

To address this problem, CIRAS pedagogical team was established in 2021 by the Universidad de Santiago de Chile and the Center for Interdisciplinary Research in Astrophysics and Space Sciences. The team is composed of high school science teachers, astrophysicists, specialists in educational sciences and pedagogy students. The objective of the team is to co-design activities based on the use of authentic data from different lines of research in astrophysics.

With the purpose of bringing frontier astrophysics topics to the school classroom in this work we present the creation of educational activities to be taught in the subject of mathematics and in accordance with the learning objectives of the secondary school curriculum in Chile.

This activity is based on the nova eruptions, which is a thermonuclear runaway triggered on the surface layer of a white dwarf as a consequence of the accreted material from the late-type main-sequence star in a cataclysmic variable star.

The eruption is observed as a sudden rise in brightness that can amount to up to approximately 16 magnitudes. A light curve of brightness decay is evident as a function of time following the eruption. Decline in light curves of novae can be complex, showing a multitude of phenomena like oscillations, plateaus, re-brightenings, etc, and the physical origin of many of these phenomena is still unexplained.

Methodology

The teaching sequence was focused on the learning objective “Apply models that describe phenomena or situations of growth and decay that involve exponential and logarithmic functions”² for mathematics class.

These activities were implemented for 87 students of 16 and 17 years old. The implementation was carried out in 3 classes of 45 minutes each, after the students have had exponential and logarithmic functions’ lectures. Students worked in groups of 3 persons and responses were collected digitally. Additionally, an individual entrance and exit ticket was applied.

In order to bring novae into the classroom, during 2022 and 2023, we acquired observing time with the training novae hunters project in the Global Sky Partners program, which is part of the Las Cumbres Observatory³. During 2023, we gained access to conduct our own observations to construct the light curve of novae that had experienced recent eruptions. Through this project, we tracked Nova Sco 2023, which erupted on April 20th of this year, reaching a maximum magnitude of 8 mag. From that point on, we maintained continuous monitoring, acquiring 3 to 4 observations per night. It’s worth noting that LCO provides calibrated images along with a photometric data table for each image.

Additionally, we improve the data acquired from Nova Sco 2023 by incorporating information gathered by amateur astronomers worldwide from “The American Association of Variable Star Observers” (AAVSO) database. In addition, we downloaded light curve data from various categories of past novae to be utilized in our teaching sequence.

Results & Discussion

In activity 2, each group of students was given a table of magnitude and time data for a recent or historical nova. With this data, they created the corresponding light curve and identified the corresponding mathematical function (Figure 1). With these graphs, all the students were able to deduce and understand that in a nova, the brightness decays over time.

In general, 95% of the students evaluated the activity positively, as the use of real data in mathematics classes provides them with a context different from the usually abstract nature of the mathematical concepts they encounter in school (Figure 2). The students responded positively to working with recent astronomical event data, as it allowed them to stay informed about the current developments in astrophysics research.

²https://www.curriculumnacional.cl/614/articles-37136_bases.pdf

³<https://lco.global/education/partners/training-novae-hunters/>

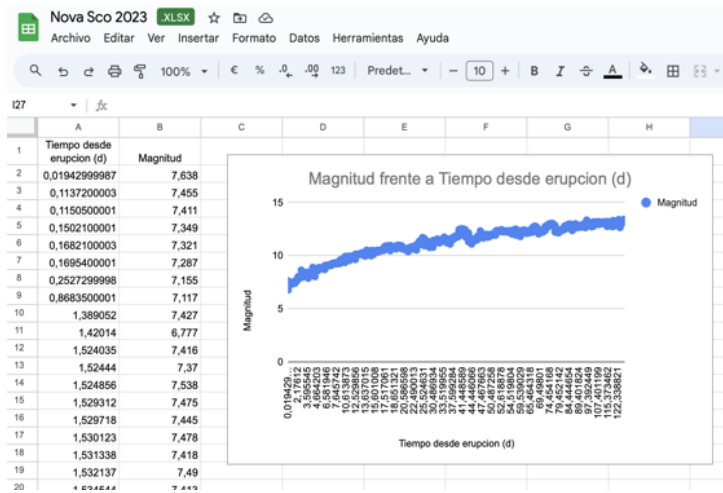


Figure 1: Graph by students for Nova Sco 2023.

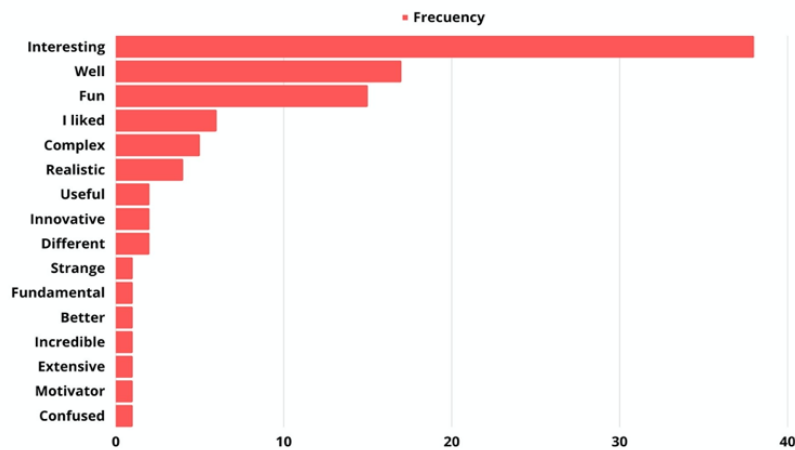


Figure 2: Responses to the question “What did you think about working with real astronomy data in mathematics class?” (N = 87).

Conclusions

The activity has allowed the use of frontier astrophysics concepts in mathematics classes, promoting the use of real data for contextualized and situated learning. With these activities it is possible to encourage students' interest in mathematics because it gives meaning to content that seems abstract. In addition, it generates interest in scientific work and the people who do it.

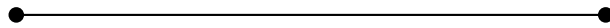
Finally, we think that the collaborative work between scientists and teachers is the key for impactful education.

Acknowledgments

This work was funded by ESO-Government of Chile Joint Committee and ANID—Millennium Science Initiative Program—Center Code NCN2021_080. The author thanks LCO by Global Sky Partners Program for providing data, and Carolina Fonseca & Fernanda Lueiza for supporting the construction of activities.

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Demonstrating Exoplanet Cloud Formation and Lightning in the Classroom

Speaker: Oriel Marshall, University of Antwerp and Copenhagen University, Denmark

Collaborators: Jesper Bruun, University of Copenhagen; Anja Andersen, University of Copenhagen; Katrien Kolenberg, Antwerp University; Peter Van Petegem, Antwerp University

Using exoplanets as a context for teaching may be an interesting way for students to think about the scientific principles at the core of a subject that hold universally, regardless of the planet being considered. For this project two classroom experiments have been developed that use simple and affordable materials such as recycled food containers and hairspray to allow students to explore the phenomena of clouds and lightning, by creating their own in the classroom. The experiments have been developed as part of the CHAMELEON exoplanet research network and are accompanied by supporting lesson materials. These materials are designed for STEM students aged 16-18 and make use of the inquiry-based learning 5E model focusing on student-led learning.



Talk link: https://youtu.be/000F__y4aAA

Exoplanets are part of a fascinating and versatile field of research that makes use of expertise in many STEM fields. The CHAMELEON Innovative Training Network (CHAMELEON, 2020) is a virtual laboratory that makes use of physical and computational modeling to research exoplanets and protoplanetary disks. One of the projects within the CHAMELEON network is an interdisciplinary project which combines education science and astrophysics. The educational materials described in this talk have been developed as part of this science-education project focusing on the translation of cutting-edge astrophysics concepts into teaching materials.

After consultation of existing materials and interviews with both teachers and exoplanet researchers, it was found that a fruitful overlap of current research in the field and secondary school curricula topics was weather phenomena on exoplanets, specifically cloud formation and the occurrence of lightning. Cloud formation is a topic that is discussed in geography curricula around Europe, and lightning comes into the physics curricula in the topics of electrical charge, triboelectricity and conductivity.

Both clouds and lightning are active topics within exoplanet research (Balduin et al., 2023; Helling, 2019b, 2019a). Computational models are a common method for learning more about

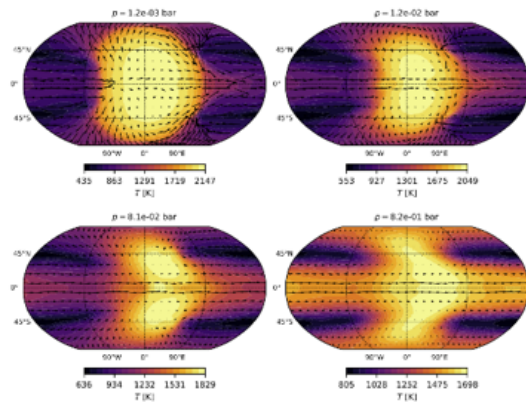


Figure 1: A computer simulated map of an exoplanet's atmosphere (Schneider et al., 2022).

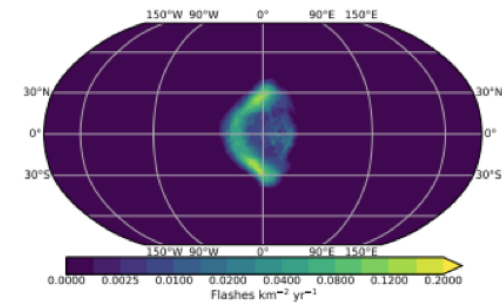


Figure 2: A computer simulated map showing predicted locations and frequency of lightning strikes on an Earth-like tidally locked exoplanet (Braam et al., 2022).



Figure 3: A diagram showing a step-by-step process to form clouds in the classroom (Oriel Marshall, 2020).



Figure 4: The materials required for demonstrating cloud formation.

these phenomena and exoplanet atmospheres in general. Some examples of these can be seen in figures 1 and 2.

Scientist-Teacher partnerships were used while developing the teaching materials on these topics (Brown et al., 2017; Trautmann & Makinster, 2005). This consisted of creating working groups of teachers and exoplanet scientists, one for clouds and one for lightning, to assist with the creation of these materials. The lessons themselves are designed using Inquiry-Based Learning (Pedaste et al., 2015), specifically the 5E model (Bybee et al., 2006). This is an inductive, student-led approach to teaching that utilizes hand-on activities for students to mimic scientists actions and behaviors. This method was selected as it acts as an appropriate parallel to the research being done by the exoplanet scientists.

The lessons are designed for students aged 15 – 18, and each lesson takes 100 minutes (2 x 50 minutes). Each lesson is centered around a physical experiment, using affordable and easily accessible materials, that have been developed in collaboration with exoplanet scientists and teachers to ensure both the scientific and pedagogical validity of the materials. Figures 3 through 6 give an overview of the experiments and the materials required for the experiments.

There are multiple reasons why using exoplanets to teach about these weather phenomena may be beneficial. Using exoplanets as a context for teaching shows the diversity of STEM subjects, for example, by showing that knowledge from geography can be applied in astronomy. Additionally, exoplanets are part of active research and so by exposing students to this, it may

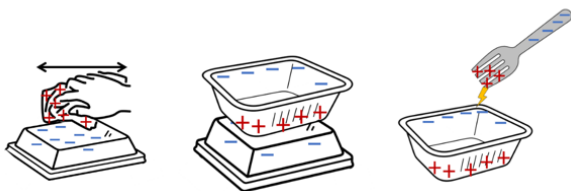


Figure 5: A diagram showing a step-by-step process to demonstrate lightning in the classroom (Oriell Marshall, 2020).



Figure 6: The materials required for demonstrating the occurrence of lightning.

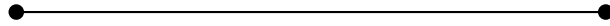
help them to better understand the scientific landscape of today. Finally, by using the context of exoplanets to teach about phenomena that also occur on Earth, it allows students to think beyond the assumptions and conditions that apply to Earth, and to identify which physical scientific properties still apply if you strip away the information and assumptions that are specific only to Earth.

The lesson materials discussed in this talk have been developed in collaboration with exoplanet researchers in the CHAMELEON network and several volunteer secondary school teachers. The materials can be found online at <https://oriellmarshall.com>.

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Origin of Life: An Interdisciplinary Approach

Speaker: Daniele Pizzo, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, University of São Paulo, Brazil

Collaborators: Elysandra Figueredo Cypriano, IAG – University of São Paulo

In the natural sciences, the areas are connect when we look at them. In this work we'll present an interdisciplinary didactic sequence on the Origin of Life, which was collaboratively applied among teachers of a public school in São Paulo. In this approach, the origin of life was treated under the bias of biology, physics and chemistry in an integrated way. The results showed that students, because they're used to isolated disciplines, have difficulty in relating different knowledge. However, it can be observed that articulating the content in an interdisciplinary way promotes a more contextualized learning for students. In the view of the teachers involved, the approach was challenging, but it demonstrated that this methodology can provide more integrated and meaningful learning.



Talk link: <https://youtu.be/zEmT5fYg-TQ>

POSTER CONTRIBUTIONS

Enhancing Primary Science Education Through Interactive Astronomy Concept Diagrams

Presenter: Ilham Bouisaghouane, The Netherlands

Collaborators: J. Holt, Centre for Applied Education Research, Amsterdam University of Applied Sciences, Netherlands Research School for Astronomy (NOVA), Anton Pannekoek Institute for Astronomy, University of Amsterdam, & NAEC chair for The Netherlands; B. Bredeweg, Centre for Applied Education Research, Amsterdam University of Applied Sciences, Informatics Institute, Faculty of Science, University of Amsterdam; P. Russo, Leiden Observatory, Leiden University

Astronomy concepts are abstract, and students find it challenging to create the mental picture to fully comprehend them. Research has shown that didactical approaches based on hands-on, minds-on learning support learners in the understanding of physical concepts. In close collaboration with The Dutch Black Hole Consortium, we created lessons using smart education techniques inspired by their research topics. The goal of these lessons is to stimulate reasoning skills by the use of computer-based interactive diagrams during practical astronomy-oriented lessons. We will introduce our interactive concept diagrams supported by hands-on practices. We will argue their benefits in primary education classes to help increase student involvement and develop adequate concept learning in the sciences.



Poster link: <https://doi.org/10.5281/zenodo.10443733>

1. Abstract

Astronomy concepts are abstract, students find it challenging to create the mental picture to fully comprehend them. Research has shown that didactical approaches based on hands-on, minds-on learning support students in the understanding of physical concepts. In close collaboration with The Dutch Black Hole Consortium, we are creating lessons using smart education techniques inspired by DBHC research topics. The goal of these lessons is to stimulate reasoning skills via computer-based interactive diagrams during practical astronomy-oriented lessons. Here, we introduce our interactive application which combines interactive knowledge representations and hands-on activities.

2. Primary Science Education

2.1 Challenges in Primary Education

To understand the necessity for interactive lesson-materials, we need to consider the main demands and challenges faced in the current (primary) educational landscape in the Netherlands. Teaching astronomy requires solid knowledge, educational skills, and appropriate methods and teaching techniques [1]. Research has shown that many teachers in primary education with sufficient pedagogical training who would like to teach Inquiry-Based Science Education (IBSE) lessons, lack the formal training in science education to teach it well [2,3]. Primary education students, on the other hand, struggle with the abstractness of astronomy concepts [4]. They also hold many intuitive misconceptions about scientific phenomena [5]. In addition, astronomy is typically taught using textbooks in the Netherlands, without any practical or other supporting activities. The lack of meaningful, rich conceptual learning materials further complicates the support for teachers and hinders students' exploration of astronomy topics [6]. Knowledge representations could provide invaluable contexts for teachers to help identify and eliminate students' misconceptions, while raising awareness and inducing scientific rigor.

2.2 Knowledge Representations: Minds-on and Hands-on learning

Interactive knowledge representations are an example of a successful tool to engage students and trigger deep learning in science lessons [7]. These representations have been proven to increase retention and comprehension, promote active engagement and are visually intuitive [9]. Teaching approaches that move away from textbooks have demonstrated a significant enhancement in the science education learning process [10]. Including hands-on and minds-on aspects into classroom science and technology activities, which go beyond sole practical tasks and involve reasoning skills, offer a solution for better implementing IBSE [8].

The Minds-On project (www.minds-on.nl) aims to combine the strengths of both practical activities (hands-on) and interactive knowledge representations (minds-on). The current project is developing astronomy-themed lessons using the Minds-On application.

3. Research plan: Knowledge Construction

Our research project comprises 4 key themes: (1) Knowledge construction, (2) Engagement in a classroom setting (with a focus on inclusion), (3) Engagement in a public area (museum) and (4) Stakeholder analysis (focusing on the state of the art, identifying opportunities, and creating guidelines). The main objective in the first theme is to develop interactive knowledge representations rooted in astronomy contexts, that enhance scientific thinking skills such as understanding cause-effect relationships and thinking in systems. The learning goals for these lessons are defined by the Dutch Primary Education Curriculum [11], with each objective linked to a specific cross-cutting concept [12]. For instance, in the lesson 'The Solar System', students are instructed and guided by the 'Minds-On' software. They engage in a hands-on activity, assessed through a minds-on 'classification tree' exercise (Figure 1), where they classify celestial bodies based on orbit, shape, and composition. The development of this diagram addressed diverse requirements, including the selection of appropriate astronomy contexts, celestial body count, and knowledge representation design.

Our lesson materials are an ongoing project, soon to undergo thorough classroom testing and evaluation.

Our goal is to develop inclusive, motivating, and captivating lessons that empower teachers to deliver enriching science education experiences beyond the standard curriculum and their

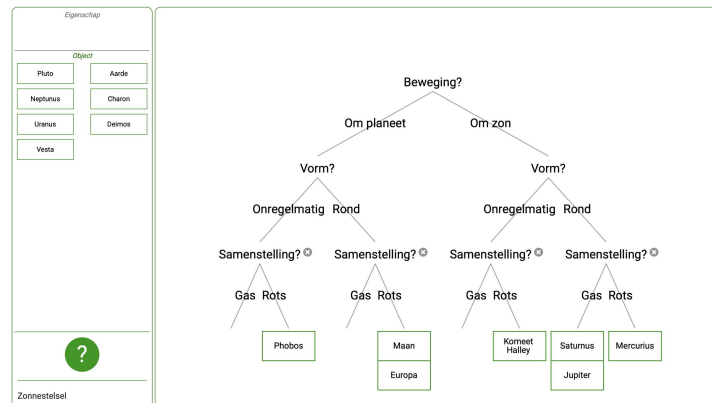


Figure 1: This diagram illustrates a Minds-On exercise on the topic ‘Solar System’ and the cross-cutting concept ‘Classification’. Students must place the 14 objects (planets, moons, minor bodies) in the classification tree using three properties (movement, shape and composition). Students are free to choose the order of the properties. For the placement of each property, once all objects are placed in the diagram, students receive feedback and, if necessary, are asked to improve their work. Once all objects are correctly placed, students can choose the next property until the diagram is complete.

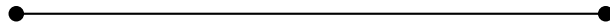
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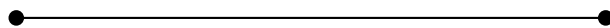


Hands-On Astro Activities in Primary Classes

Presenter: Danijela Takac, Croatia

Teaching astronomy in primary classes is challenging and most rewarding subject you can teach. Students are full of wonder and imagination. These activities are most creative and most rewarding for a teacher. The downside of primary classes is that, since stargazing is very challenging cause of the students young age, all the activities have to be done in the classes. We will show physical and team-building activities like training like an astronaut, creative activities such as painting stars and space with plasticine, and crafty activities like making and launching a rocket. Teaching primary classes boosts teacher creativity and storytelling too.

Poster link: <https://doi.org/10.5281/zenodo.10443740>



High-School Students Interested in Astronomy Use a Remote Observatory to Carry out Projects

Presenter: Jure Japelj, University of Nova Gorica, Slovenia

Collaborators: Andreja Gomboc, Center for Astrophysics and Cosmology, University of Nova Gorica, Slovenia

University of Nova Gorica (Slovenia) and astronomical magazine Spika run the GoChile project, which uses two small telescopes at the El Sauce Observatory in Chile. The two remotely operated telescopes are primarily intended for teaching — significant telescope time is reserved for secondary school students interested in astronomy. Through the project, the students gain experience in observations and get introduced to the process of scientific research. I will present our activities in the past two years: remote teaching, mentoring of research projects, and the organization of two summer schools. Interestingly, there has been a great interest in the telescope among girls, which was particularly evident in the summer schools, where more than half of the registrants and participants were girls.



Poster link: <https://doi.org/10.5281/zenodo.10443757>

In 2021, the University of Nova Gorica (UNG), in collaboration with the astronomical magazine Spika, installed two telescopes at the El Sauce Observatory in Chile. The project aimed to offer the UNG's students and Slovenian high-school students a telescope standing at a site with excellent observing conditions. The project, which is first and foremost educational, was named the GoChile project.

The two telescopes stand on the same mount. Both telescopes are equipped with a camera and a set of filters. The bigger GoT1, a 40 cm reflector, is used to observe and study asteroids and comets, planets' moons, stars (e.g., cepheids or other types of variable stars), exoplanet transits and transients (primarily supernovae and microlensing events). The smaller GoT2 is a 7.2 refractor used for astrophotography. Observations are conducted remotely by connecting to the computer at the site in Chile via a remote desktop application.

In September 2021, we started advertising the telescope and the project to high school teachers to get the word out and attract interested high-school students (in the following students). Our target was the group of students who already had a basic grasp of astronomy but wanted to take the next step in astronomy. We hold regular seminars for teachers and students to teach them

how to observe with GoChile and acquaint them with basic analysis techniques like astrometry and photometry. We also provide a lot of individual supervision.

Students do different activities.

- Simple projects: Students get acquainted with the telescopes by doing simple projects like astrophotography and observing exoplanet transits or variable stars. They learn how to plan and carry out remote observations as well as the basic techniques of data analysis (astrometry and photometry).
- Research projects: Students carry out advanced projects where the focus shifts to a scientific result. Examples of such projects are measuring distances to cepheids, simple modeling of an exoplanet transit, obtaining an SN Ia light curve and using it to measure its distance, and making an HR diagram of a cluster.
- Summer schools: We have organized two summer schools. Each school was attended by 16 students who learned to observe with the GoChile telescopes, carried out projects, and listened to lectures. We also helped those who wished to write an article about their work, which was later published in one of the astronomy or science-oriented magazines.

The project is aimed at highly motivated students, meaning, the reach is relatively small: about 60 students have used the telescope in the past two years. However, for many of these, our project is the only way for them to improve their astronomy skills and get a glimpse of what actual research looks like. Students' interest in our project — our telescopes are almost fully booked, and the number of applications for the summer schools was twice the number we could accept — shows that this particular group of promising students wants (and needs) such a project for their development.

Surprisingly, the boys-girls ratio of student users is about 50-50 percent. The girls have carried out the same number of research projects and were in the majority at the summer schools. The stark contrast between their interest in our program and their disinterest in the national astronomy competition (and therefore absence at the astronomy Olympiad) might reflect an insufficient encouragement of girls for science at the primary and high-school level in the education system.



The Starry Night Defenders: Integrative Astronomy Curriculum About Dark-Sky Social Innovation

Presenter: Exodus Chun-Long Sit, FRAS Chair of IAU-NAEC & Co-NOC Hong Kong, Starrix, Hong Kong

Light pollution has always been advocated and promoted by astronomers and science communicators. However, artificial light at night (ALAN), as a crucial topic of environmental issues, has rarely been mentioned in the science curriculum in formal education. Beside motivating students through self-learning educational resources, how can we apply dark-sky education in general science learning? ASTROx is an interdisciplinary project that aims to solve real-life problems related to astronomy. The contribution will showcase a student-led social innovation project “The Starry Night Defenders”. Through a holistic design thinking process, students will explore different methods to redesign dark-sky-friendly light shields and ways for dark-sky advocacy.



Poster link: <https://doi.org/10.5281/zenodo.10444792>

The STEAM+A@Astronomy project has been launched for more than five years. We had started a new highlighted social innovation project called “The Starry Night Defenders”. Concerning the light pollution issues in Hong Kong, we wish to cultivate and motivate learners to be aware of the urban light pollution issues and the artificial light at night (ALAN) by taking action through popular science communication and dark sky advocacy.

It began with the United Nations’ 17 sustainability development goals (UNSDGs), which had come to the discussion that there are many essential elements, including “Quality Education” and “Sustainable Cities and Communities”, which might be closely related to astronomy aspects and environmental problems that we are facing in Hong Kong with light pollution. Social Observation through Frame Within a Frame Photography is a hands-on experiential learning activity. Students can use their DIY photo frames to observe their living communities, understanding how living quality and wildlife are affected by excessive outdoor lighting of facilities and human activities. They would have chances to share their thoughts and photos (as learning outcomes of social observation), and provide possible solutions through innovative design thinking. Using a Photo Frame to see the real world could help the learners to focus on observing actual problems in our real life, as we usually easily overlook some important details in our daily lives.

Besides, it was followed by an inquiry-based learning of light pollution interactive maps through digital devices. It was a precious opportunity to develop digital scientific literacy and empathy



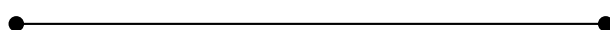
Figure 1



Figure 2

by understanding that there are many places in the world that are affected by serious light pollution. Through the popular science lesson, students acquired astronomical knowledge about seasonal constellations that can be seen in Hong Kong through digital star maps and educational technology (EdTech) tools.

To celebrate International Dark-Sky Week 2023, not only did the team members produce the promotional videos and prepare the elevator pitch at Dreamstarter Pitching Day, but they also designed posters and contributed to hands-on learning with core values of “DARK” (D for Design, A for Art, R for Responsibility, K for Knowledge). The Starry Night Defenders also designed prototypes of DIY Lights-Up Constellation (Fig. 1). It was designed to promote the celestial objects in the night sky celebrating the 100th anniversary of 88 constellations. Another featured prototype was DIY Dark-Sky Friendly Light Shields (Fig.2) to reframe the design of lighting with simple elements. More encouragingly, their efforts paid off and the prototypes had precious opportunities to showcase Dreamstarter Fair 2023, and the university’s Coding and STEAM Fair 2023.



Students Generate Fantasy Scenarios Based on Their Learnings of Astronomy. Engagement Evaluation

Presenter: Cuauhtemoc Mendez, Tec de Monterrey / TRIBU cultura astronómica, Mexico

Collaborators: Dr. Katie Berryhill, CAPER

The final work of the Tec de Monterrey Astronomy course has been the elaboration of a fantasy trip to space. The students show what could be tourist attractions of places in space seen in the course, and also use their knowledge of Biology, Chemistry, Physics, and Astronomy, to produce unreal situations based on their learnings, be it the appearance of possible inhabitants, or the typical food of the place. Students' presentations are regularly beyond what is necessary for the course, which is a sample of the engagement achieved in it, according to the bibliography consulted for the evaluation of engagement in the course.



Poster link: <https://doi.org/10.5281/zenodo.10444796>

The use of a final project that considers topics of the Astronomy course but also other topics that students seek on their own, in addition to elements of art and science-based fantasy, generates greater student engagement in their project and with it also in the course. These types of projects are attractive to young people with different vocations and help them perceive the relationship that sciences have with each other. This becomes especially important for schools in Mexico that are not known for engaging students in topics, especially those related to science and mathematics.

The Astronomy 101 course is taught at high school level. Astronomy is not a topic regularly found in the school curricula in Mexico. This is one of the reasons why these types of course attract the attention of students. It is an optional course that students choose. This regularly reflects a greater enthusiasm of students to learn about the topics on their own. This course has been transmitted virtually since the pandemic and this allows us to have students from different campuses throughout the country, while allowing a perception of belonging to the same educational system.

Mexico does not have an important development in the Space Industry, and Astronomy is not a regular part of the topics taught in schools. However, it generates a natural curiosity in the public and a special enthusiasm in students who have the option of taking topics related to



Figure 1: Invitation for the final project's presentation.

space sciences. From an educational point of view, Astronomy has an obvious effect: It awakes a natural curiosity about Space, probably because the news of developments related to space exploration and the development of new technologies.

The Astronomy 101 course at Tec de Monterrey was designed to cover basic concepts, mainly related to the Solar System, although some galaxies are also mentioned. Topics are presented to show their relationship with basic sciences that they took in the previous years, such as Physics, Chemistry, Biology, and Mathematics.

The students who enroll in the course show different vocations, so it is important for the team project to have different perspectives, from technical issues that involve basic sciences, Astronomy topics, and also creative and art aspects. For this reason, the final project of the semester is an activity that involves the learnings of the course but also gives rise to findings done by students to delve deeper into a particular aspect, in addition to the creative fantasy part.

It is worth mentioning that for the final presentation, students are encouraged to invite their friends from other courses to accompany them. These guests add to the engagement that students have in their presentation, in addition to sowing interest in possible future students of the course (Fernández-Zabala, Goñi, Camino, & Zulaika, 2015).

Among the topics they have chosen, at least 40% correspond to areas of Space that were not seen during the course. This reflects students invest time outside of the course in reading more and delving deeper into areas of their own interest (Appleton, Christenson, Kim, & Reschly, 2006).

At the beginning of the last partial of the semester, the instructions for the activity are presented: Creation of a tourist trip to a destination in Space. Students will choose the destinations they want; it does not matter if it was seen in class or not.

The destinations categories are:

1. Solar system object: includes planets (even exoplanets) and moons, dwarf planets, asteroids,

- and comets. This should be a specific object, not a region like the asteroid belt or Kuiper belt.
2. Star or star cluster: includes single stars, multiple star systems, star clusters (globular or open), neutron stars, or white dwarf stars (if one of the last two, you can include the surrounding nebula in your discussion. Do not choose a whole constellation as those stars are not physically associated with each other.
 3. Nebula: includes any of the types of objects called nebulae: star-forming regions, planetary nebulae, supernova remnants.
 4. Galaxy: includes individual galaxies or galaxy clusters (do NOT choose the Milky Way Galaxy).

Students need to include the following:

1. **LOCATION:** A guide for finding the object in the night sky so their friends and family back home can point to where they are. It can be in a constellation that we learned in class or one of the others. They must include a graphic of the constellation with the object's location clearly marked.
2. **TOUR GUIDE INFORMATION:** Brief description that a tour guide might tell tourists about the object when they visit. What kind of object is it? How old is the object? What is the size of the object? How far from Earth is the object?
3. **POSTER:** Design of the principal selling material about the tour about to be presented. This can be done like a post card, social media posts, or a quick blog or vlog post. Interesting highlights/cool facts about the object (real and fantasy: local food, local fauna, local tourist destinations and activities). What interests you the most about the object?

Every final presentation is quite an event. Students from other courses, and even teachers ask to be part of the event. This activity is an opportunity for them to share their joy for space, for science, and for Arts also.

This activity was kindly shared by Dr. Katie Berryhill during a Symposium for Astronomy teachers, held by CAPER (Center for Astronomy and Physics Education Research) in Baltimore MD. And one truly special aspect is that every semester Dr. Berryhill finds the time to be part of the event. Via Zoom, she listens and congratulates every team. Students feel very important to be in contact with an international Astronomer.



Youths Can Strengthen Planetary Defense by Combining Open Science with Technology in Classrooms

Presenter: Arushi Nath, Founder MonitorMyPlanet.com, Canada

The pace of discovery of near-Earth asteroids outpaces current abilities to analyze them. Knowledge of an asteroid's physical properties is essential to deflect them. I have developed open-source algorithms for classrooms that combine images from robotic telescopes, open-data, and math to determine asteroids' size, rotation, and strength. I took observations of the Didymos binary asteroid, and my algorithm determined it to be 820m wide, with a 2.26-hour rotation period and rubble-pile strength. I measured a 35-minute decrease in the mutual orbital period after impact by the 2022 NASA DART Mission. External sources validated the findings. Every citizen scientist is now a planetary defender. The project won the 2023 Youth Astronomy Award of the Royal Astronomical Society of Canada.



Poster link: <https://doi.org/10.5281/zenodo.10444993>

Introduction:

There are over 32,000 known near-Earth asteroids as of May 2023, and hundreds of new ones are discovered every month. If an asteroid were on a collision course with the Earth, the deflection strategy would depend on the physical properties of the asteroid, such as its size, rotation period, strength, and the presence of a moonlet. Unfortunately, the rate of discovery of near-Earth asteroids outpaces the current ability of astronomers to analyze them.

My project had two goals:

1. Develop algorithms that citizen scientists can use to accurately determine an asteroid's physical properties using observations from robotic telescopes, open data, and school-level math.
2. Apply the algorithms to a real-world scenario to determine the physical properties of the Didymos binary asteroid and measure the success of NASA's Double Asteroid Redirection Test (DART) Mission in deflecting Dimorphos, the moonlet of Didymos.

Methodology:

I wrote research proposals to get observation times on robotic telescopes in Australia, Canada, Chile, and Spain. I imaged the Didymos binary asteroid for over 55 hours before, during and after the DART spacecraft impact.

Using open data, weighted mean, and area of a circle formula, I centroided known stars and asteroids in the images. The correct aperture size was calculated to measure the pixel brightness of Didymos across all images using the slope and median functions. I eliminated variations in the asteroid's brightness due to changes in weather and seeing conditions using comparison stars of known and constant brightness.

As asteroids orbit the Sun, their brightness varies because their distance from the Sun and Earth changes. I adjusted for these changes by calculating unity distance, phase angle and light time correction offsets, resulting in the asteroid's absolute magnitude and size. As asteroids are irregular in shape, different sides reflect different amounts of light, allowing measurement of their rotation period. My algorithm fitted the asteroid's time-series absolute magnitude from individual observations and combined them into composite light curves of different periodicities. The asteroid's rotation period was the periodicity of the composite light curve corresponding to the smallest root mean square error. In the case of binary asteroids, subtracting the rotation period from the composite light curve yields their mutual orbital period.

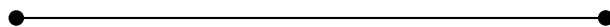
Results:

The methodology was transformed into an algorithm for citizen scientists using Python functions and Numpy, Matplotlib, and Astropy libraries. The algorithm found the optimal aperture size, comparison stars, offsets, and merged observations from different observers and multiple nights to determine an asteroid's physical properties. Applying the algorithm to observations of the Didymos binary asteroid revealed its size to be 820 metres with a 2.26-hour rotation period. Post-impact, I measured a 35-minute decrease in the mutual orbital period of Dimorphos around Didymos. The brightness of the Didymos system increased by 1.2 magnitude because of the sunlight reflected from the ejecta, and I measured the ejecta tail to be 20,000 km long.

Using the size and rotation period calculations, I determined Didymos to be of rubble-based strength. Applying Kepler's third law of the relationship between orbital period and radius, the reduction in orbital period by 35 minutes post-impact yielded a 40-metre decrease in the orbital radius of Dimorphos — validating the success of the DART mission in deflecting Dimorphos.

Conclusions:

All project goals were achieved. Algorithms were developed to accurately determine the physical properties of near-Earth asteroids by combining images from robotic telescopes and open data. When tested on a real-world scenario, the algorithm determined the physical properties of the Didymos binary asteroid and confirmed the success of the deflection of Dimorphos. My results matched those produced by the NASA DART Mission. I have made my algorithm open source so that citizen scientists can accelerate the pace of analysis of near-Earth asteroids and become planetary defenders.



Astronomy for All Age Groups

Presenter: Shylaja B S, Jawaharlal Nehru Planetarium, India



Poster link: <https://doi.org/10.5281/zenodo.10445007>



The sun, moon, and stars have remained a fascination from time immemorial but have not entered the classroom in the strict sense. On the one hand, this is a handicap; on the other hand, it takes only those really interested in the subject to serious reading.

However, it is important that every one should be taught some elementary ideas on that part of astronomy classified as positional astronomy. The messages circulated on social media reveal the level of ignorance. Basic concepts on the reason for seasons, meaning of equinoxes and solstices, or simply the meaning of the Tropic of Cancer and Capricorn have remained elusive for a common man. The phases of moon are known from calendars and not by looking at the sky, leading to awkward depiction in TV serials and cinemas.

The situation was completely different about a 100 years ago. We see references to finding the time of the year / time of the night by looking at the night sky. Thus, the words like blue moon and supermoon get misinterpreted and hyped.

Our festivals, literature (both classics and folk), proverbs commonly used have some astronomical ideas incorporated in them. The luni-solar calendar followed all over India and neighbouring countries, requires a good understanding of the motions of the sun and the moon. Instead of complicating the explanation with mathematics, it would be best to show the night sky as a demonstration. The best example is the addition lunar month added every fourth year. Following the position of the full moon every month clarifies the concept. That also explains why the names of the months are derived from the star names.



Figure 1: The festival of the birthday of Lord Krishna is celebrated at midnight when the moon is next to Aldebaran (Rohini); this fixes the time of the year as well as the time of the night. The maps correspond to the festival dates of 2022 and 2023.

Thanks to the advances in space technology, the knowledge on planets have escaped from the clutches of the astrologers. Still, the planetary events like conjunctions and oppositions need a clearer understanding.

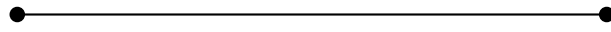
Here, I plan to describe how different concepts of astronomy can be integrated in teaching all age groups, not necessarily within the four walls of the classroom. Events like eclipses and conjunctions kindle the curiosity which should be exploited. However, preparing them for understanding and watching the event would make it much more enlightening.

Comets and meteors provide opportunities to guide the common man to the sky, since they demand exposure to some basics on constellations. Spending about half an hour under the sky would be easy. Trying to predict the position of moon or planets for the next day would be a thrilling experience. The relation of a festival with the position of the moon near a specific star can be verified. (The birthday of God Krishna is celebrated on 8th day after full moon, and the moon necessarily is next to Rohini / Aldebaran rising at midnight). Such observations can trigger their quest for understanding the motion of heavenly bodies.

The celebration of zero shadow days is picking up in the last few years making people wonder about the importance of the day.

The spherical dome of the celestial sphere cannot be convincingly displayed on a 2-dimensional screen. This handicap is eliminated in planetariums, which are becoming very popular. The radio shows therefore were very popular since they could reach a larger audience. The passages of ISS and HST are very handy tools for the purpose. These moving dots serve as pointers in the sky. The Covid lockdowns generated innovative ideas. In this modern era of internet, with online meets and even small videos are of great importance. The best example is the launch of the Chandrayaan II mission to the moon; every person heard about the functioning of the lander just for 15 days and sought to understand the reason by the month-long exercise of observing the moon.

The routine observations of the night sky would go a long way making them understand the vastness of the universe.



Developed a Progressive Astronomical Science and Education Model Around Night Protection

Presenter: Shen Xinrong, Jiangsu Tianyi High School, Jiangsu Autonomous Learning Institute, China

Collaborators: Zhouyi Shen, Wuxi Tianyi Experimental School, China

The Astronomical Society of Jiangsu Tianyi High School has carried out practical exploration around “Dark Night”, forming a popular science education model with a progressive curriculum design including popularisation, academic and research courses. This model stimulates students’ interest through science popularization courses, consolidates students’ knowledge through academic courses, and guides students to solve problems through research courses. Over the past decade, the Tianyi model has achieved remarkable results. A number of papers on “Dark Night” have been published in SCI and other academic journals in and out of China, and a number of related projects have won awards in the academic competitions in and out of China.



Poster link: <https://doi.org/10.5281/zenodo.10444784>

The Astronomical Society of Tianyi Education Group, including Tianyi High School, Tianyi Experimental School, etc, had carried out practical exploration around “Dark Sky Protection”, forming a popular science education model with a progressive curriculum design including popularisation, academic, and research courses. This model stimulates students’ interest through science popularization courses, consolidates students’ knowledge through academic courses, and guides students to solve problems through research courses.

1.Popularisation courses: Based on the typical characteristics of each discipline, taking activities and personal involvements as the fundamental form, and students’ interests cultivation as the prime objective, it targets the whole campus by carrying out popular science lectures and

events. For example, popular science lectures, exhibitions, and photography competitions on light pollution.

2. Academic courses: Based on the core info of each discipline, taking the intensive training as the main form and solid achievement in both knowledge and skills as the prime objective, it targets the students' associations by carrying out theoretical studies and observational practice. For example, Literature study related to light pollution, legal study related to urban lighting, and case study related to DarkSky International; Guide students to conduct surveys on night sky luminosity and street light illumination, Guide students to analyze night light remote sensing data; Learn from experts from Purple Mountain Observatory, the University of Hong Kong, GFZ German Research Center for Geosciences and other institutions.

3. Research projects: Based on project researching in each sub-discipline, taking research ability improving as the prime objective, it targets the scientific teams and individuals. For example, Investigation of Night Sky Photometry in Wuxi City, Research on Night Light Monitoring Based on GaN-MN Network, Research on Campus Lighting System Design Based on Ecological Concept, Exploration of Campus Intelligent Street Lamp Layout Design Based on Wireless Technology and Physical Models, etc.

The Astronomical Society of Tianyi Education Group has carried out a series of extraordinary research independently or in cooperation with world-leading institutions, and achieved fruitful results.

In recent years, multiple papers on "Dark Sky Protection" have been published and have won awards in national and provincial competitions. The teachers and students of Tianyi Education Group have been invited multiple times to give presentations on "Dark Sky Protection" at academic conferences both domestically and internationally. A group of students entered top universities to continue their studies in astronomy, such as Peking University, Nanjing University, Princeton University, Cornell University, etc.



Igniting the Astronomical Spark: Unconventional Approaches to Teaching Astronomy

Presenter: Carolina Escobar Garcia, Galileo Teacher Training Program, Colombia

Even though, in an ideal world, everyone would have access to astronomy, that is not the reality for millions of people all over the world, and in Colombia, this happens even in the main cities of the country. Helios GTTP has created and carried out educational and outreach activities applying modeling instruction methodology and hands-on activities with communities that are not able to attend the planetarium or astronomy club's activities and also are not considered the target audience because of geographical location, beliefs, or even prejudice.



Poster link: <https://doi.org/10.5281/zenodo.10443745>

Astronomy is often perceived as a gateway to the cosmos, igniting curiosity about the universe and promoting scientific literacy. Educational and outreach programs in astronomy have traditionally centered around educators, children, families, and students already drawn to the field. While these programs have successfully nurtured interest within these groups, they have left behind underserved communities, including refugees, internally displaced children, and religious organizations. This essay delves into the educational gap that exists in astronomy programs and the importance of extending the reach of this fascinating field to marginalized populations.

The Gap in Astronomy Education

The stark underrepresentation of underserved communities in astronomy education is a critical concern. The deficiency is especially pronounced in rural and underserved regions, where astronomy outreach activities are scant or virtually absent. Urban areas and schools with established science programs tend to receive the lion's share of attention, exacerbating the existing educational inequalities.

The Impact of Neglect

Neglecting underserved communities in astronomy education has far-reaching consequences. Firstly, it perpetuates educational inequalities and limits the potential for individuals in these communities to pursue STEM (Science, Technology, Engineering, and Mathematics) fields. The absence of diverse voices within the scientific community stifles innovation and scientific progress. Fostering an inclusive approach to astronomy education can help in addressing this underrepresentation.

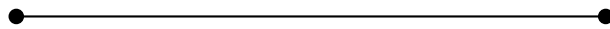
Moreover, neglecting these communities hinders social integration and inclusion. In the case of refugees and internally displaced children, astronomy can serve as a unifying force, transcending cultural and linguistic barriers. It can provide a common ground for individuals who have experienced displacement and trauma, offering a path to healing and learning.

Initiatives Bridging the Gap

Some organizations have recognized the urgency of closing this educational gap. One exemplary initiative is the HELIOS - Galileo Teacher Training Program in Colombia. This program has not only acknowledged the need to expand astronomy education to underserved communities but has taken concrete steps to bridge this divide. It has successfully developed and executed outreach and educational activities aimed at teaching these communities about celestial phenomena, including the Sun and eclipses.

Conclusion

In conclusion, the omission of underserved communities from astronomy education is a systemic issue that deserves attention and action. Access to quality astronomy education can empower individuals, regardless of their background, to explore the marvels of the universe and cultivate a passion for science. By proactively extending these opportunities to marginalized populations, we not only enrich the lives of individuals but also contribute to a more equitable society. In this endeavor, knowledge knows no boundaries, and we can unlock the full potential of astronomy education as a means of fostering curiosity, diversity, and unity. The pursuit of the stars should be an inclusive journey accessible to all.



Harnessing Infographics for Astronomy Education in Resource-Limited Regions: The Case of Iraq

Presenter: Ali Al-Edhari, Al-Muthanna University, Iraq

In the digital era, effective science communication requires novel tools like infographics. They simplify complex concepts, making science, especially astronomy, accessible to broader audiences. This research emphasizes the use of infographics in advancing astronomy education in resource-limited regions like Iraq. The conversion of intricate data into visuals allows for easy understanding, fosters self-paced learning, and engages larger audiences. Furthermore, their cost-efficient production provides a sustainable educational alternative for resource-constrained areas. Ultimately, infographics could significantly enhance scientific literacy in regions with limited astronomical resources, inviting more exploration of their impact across various scientific disciplines.



DISCUSSION SUMMARY

Accessibility took centre stage in the discussions from the education in practice sessions. Practitioners and educators are increasingly dedicated to working with underserved groups and communities, a pursuit that inevitably presents various challenges. The discussion delved into strategies for engaging with schools in rural areas. Anne-Marie Wijmans encouraged practitioners to collaborate with others who have better accessibility to these areas and to plan visits to multiple schools in the same geographical areas to optimise travel and time efficiency. Rosa Doran highlighted the value of 'training the trainers' and training teachers to create a ripple effect. This approach ensures that learning and techniques are disseminated to colleagues and, consequently, more pupils benefit.

Emma Wride underscored the essential nature of funding, particularly for schools that are underserved and struggle to acquire even basic materials like pens and paper for pupils. The discussions emphasised that efforts need not focus solely on providing access to remote, expensive, high-tech telescopes and software and computers. The talks from Emma Wride, Anne-Marie Wijmans, and Oriel Marshall demonstrate how we can strip things back and use simple, affordable materials and resources and still have a substantial impact on young people.

Apparent across all the talks were themes of inquiry-based learning: learning by doing, asking questions, and getting hands-on and creative. While widely advocated in science and astronomy education literature, there is a growing concern that such an approach can exacerbate the gap between higher-performing pupils and lower-performing pupils or those who have additional learning needs. The latter group is less likely to have the confidence to ask questions and may feel they have less existing knowledge to contribute. There were therefore discussions about how inquiry-based approaches can be more equitable.

Ignacia Benito-Cisterna stressed the importance of teachers individually engaging in the activities first, undergoing the entire process to understand how it would operate in a classroom environment. This enables the identification of potential barriers, e.g. sufficient time, clear instructions, etc. before full implementation. Jorge Rivero Gonzalez encouraged practitioners to not jump in too deep with inquiry but to slowly build up the process, with gradually less support and scaffolds. This approach works best when implemented over time, and through collaboration with teachers to thread it through the culture of learning within the school. Conversations also highlighted the importance of multi-modal learning, challenging the common reliance on visual tools in astronomy education. A key takeaway from Nic Bonne's talk was how utilising different senses - touch, audio, visual - which allows pupils to access their learning in ways they are most comfortable with, thus maximising the benefits they derive from their educational experiences.

Speakers discussed the importance of co-development and partnerships with teachers. Oriel Marshall shared insights into her co-development approach between both teachers and research scientists. She emphasised the transformative impact of including teachers in the process: fostering a sense of ownership and confidence when implementing the materials. This is particularly valuable with teachers who are non-specialists and who may be unfamiliar with topics of astronomy. Nic Bonne also emphasised the pivotal role of teachers in understanding students' unique learning needs and preferences. He encouraged practitioners to engage in

ongoing conversations with teachings, seeking their input both before development and after implementation of material to inform a continuous refinement of their practices.

Discussions also touched upon the importance of ensuring pupils are aware of the access they have to opportunities and careers. Ignacia Benito-Cisterna highlighted the geographical advantage of Chile as a research-intensive country hosting major telescope observatories. Despite this privilege, the school curriculum in Chile lacks comprehensive astronomy content. Consequently, pupils are often not aware of Chile's prominent position in the field of astronomy, as it is not a subject they regularly encounter. The discussion emphasised that even when opportunities appear to be 'on their doorstep', pupils still require support and communication to recognise and embrace these opportunities. Without it, valuable prospects can slip by unnoticed.

Astronomy Education Research and Evaluation

Session organisers: Sophie Bartlett (OAE Heidelberg), Julia Plummer (Pennsylvania State University, USA), Saeed Salimpour (OAE Heidelberg), Joanna Holt (NOVA, NAEC Netherlands)

SESSION OVERVIEW

This session focused on research and evaluation of the underlying learning methods and approaches in astronomy education. Speakers presented a variety of applied research methods they have used to explore teaching and learning in terms of (for example) higher-order thinking skills, systems thinking, inquiry-based learning, 'being a scientist,' spatial thinking, and more. Evidence of promoting diversity, equity, inclusion, and belonging in the classroom featured heavily across the presentations.



TALK CONTRIBUTIONS

Status of Astronomy Education in India: A Baseline Survey

Speaker: Moupiya Maji, Inter-University Centre for Astronomy and Astrophysics; Office of Astronomy for Education, India

Collaborators: Surhud More (OAE India, IUCAA), Aniket Sule (OAE India, HBCSE)

As a first step towards improving astronomy education in schools, we at the OAE India Center are conducting a baseline survey to understand the status of astronomy education in India. In this survey, we investigate student perceptions about various facets of astronomy education, e.g., astronomy content in their syllabus, general interest, and connections of their cultural knowledge with astronomy. This survey was conducted nationwide in 10 languages with over 2000 students across many different environments. The data revealed that, although students are interested in astronomy, even basic astronomical concepts remain poorly understood. This data will be very useful to develop an improved astronomy curriculum in the future and will guide us to develop effective teacher training programs.



Talk link: <https://youtu.be/q485u6PAyzo>

Introduction:

Astronomy education at the school level is important because it is a unique subject in many aspects; the vast spatial and temporal scales of astronomy can give students a much broader perspective, it can demonstrate the interdisciplinary aspects of science, and above all, it can inspire students to connect better with science subjects in general. However, this potential of astronomy has remained severely under utilised in India. In the school syllabus, astronomy content is very limited; it is generally taught as scattered chapters in science, geography, or environmental science book, and that too mostly just till class VIII. So one of the main goals of the IAU Office of Astronomy for Education (OAE) Center India is to improve astronomy education in schools. For this, we need to first evaluate the current status of astronomy education, then identify the areas to improve upon and eventually build a better curriculum. In this project, we are working on the first step, and to that end, we are conducting a baseline survey to investigate student perceptions about various facets of astronomy education.

Background of the survey:

Over the years, several studies (Slater 2015, Bailey 2009) have been conducted to investigate the astronomy knowledge of students. However, most of the efforts in Astronomy Education Research (AER) have targeted either undergraduate students or early education (K-4). AER research in the field of middle and high school education is generally sparse. The few surveys done with high school students are either based on specific narrow topics (concept inventories or CI, e.g. Williamson 2013) or country-specific (Sadler 2010). The field of AER is still at a nascent stage in our country and no such survey has been done before in India. Thus, such a survey can lay important groundwork for further AER research here.

We conduct this survey with students in class IX because most of the astronomy content is covered by grade VIII. The survey is completely anonymous and we take informed consent from all participants: students, teachers, and school principals. In a large and diverse country like India, we need large-scale surveys to uncover the real underlying picture. The survey has been done with approximately 2000 students in about 30 schools across 11 states in a variety of environments (such as urban school, rural school, different school boards, medium of instruction, etc). It has also been translated to 10 languages for accessibility.

The initial versions of the survey questions were inspired by discussions with teachers, students, and researchers, along with other AER surveys. We also made sure that the questions reflect the Indian context properly. Before rolling it out nationwide, we conducted a pilot study where we surveyed 268 grade IX students from two schools. We analyzed the responses, and based on student feedback, the survey questions were refined, and we arrived at the final version.

The full analysis of the data is ongoing. In this talk, I will present results from our preliminary analysis with 652 students in 8 schools in the state of Maharashtra, in Western India.

Survey questions and analysis:

Our survey instrument consists of 16 questions, and they can be divided into five sections: astronomy in the curriculum, general astronomy knowledge, cultural connection, exposure to astronomy, and further interest.

We find that a large fraction of students (82%) like astronomy in general. However, many students struggle with basic astronomy concepts, e.g. distance scale, mass scale, and moon phases. For example, only 60% of students correctly arranged “Jupiter, Moon, Earth, and Sun” from smallest to largest. When asked to ‘Arrange Sun, Moon, Stars, and Neptune from closest to farthest (from Earth)’, only 32% of students could correctly answer. In a question where students are asked to choose the correct image (from a list of 9 images) for given moon phases (New Moon or Day 0, Day 2, Day 8, Day 11, Full Moon), about 80% students could identify full moon and new moon, but on average, only about 34% could identify the other three phases. Looking at the overall data, we find that only 9% of students have answered all phases correctly. These results show that the concepts of mass, distance scales, and moon phases are not clear to students.

To explore if students connect cultural events with astronomical phenomena, we asked if they can name any festivals that fall on Full Moon and New Moon Day and found that about 70% of responses were correct. On the other hand, for a question probing their beliefs in astrology, 76% students said they do not believe in it. Exposure to astronomy is mainly through online

resources and students' access to telescopes (34%) and planetariums (23%) is limited.

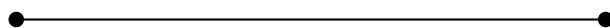
Finally, a large fraction of students (76%) are interested in learning more astronomy in higher classes. However, when asked if they would like to be astronomers, only 49% of students answered affirmatively and almost none of them knows the career path to do so.

Our preliminary analysis shows that although astronomy is a fascinating subject for students, basic astronomy concepts remain poorly understood and access to guidance and resources related to the subject is very limited. We are currently running the full analysis with all data. In the next step, we will look further into the data and analyze if the gender of the students, the socioeconomic background of the schools, or medium of instruction (i.e., English medium vs vernacular) affect the statistics in any way.

Results from this survey will help us to identify the gaps in student understanding and thus guide us to design effective teacher training programs and also help us to create an improved astronomy curriculum.

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The Effects of Laboratory and Visual Representations on Student' Understanding of Seasonal Changes

Speaker: Italo Testa, Department of Physics "E. Pancini" University Federico II of Naples, Italy

Collaborators: Silvia Galano, Universita' Federico II, Italy

In the present study, we combined two approaches to teach seasonal changes: laboratory activities and specially designed images. To investigate the effectiveness of the interplay between the two teaching approaches, we adopted a 2x3 experimental design: we randomly assigned 9th grade students to a "laboratory" and a "no laboratory" condition while both groups received instruction under one of the three conditions: "textbook images and text", "teaching booklets with specially designed images and text", "only text". Overall, we involved in the six experimental conditions 337 students. A draw-and-explain task and a multiple choice/true false questionnaire were used as research instruments. Results show a significant interaction effect of the two teaching strategies.



Talk link: <https://youtu.be/qMRAPnt-fBo>

1. Introduction and aims

Previous research has shown that students' misconceptions about seasonal changes are resistant to traditional teaching [1]. Moreover, some authors have pointed to the difficulty of reading and interpreting images as a relevant factor that may influence the persistence of such misconceptions [2]. In two previous studies [3-4], we have shown that: (i) laboratory activities can improve students' understanding of the mechanism underlying seasonal changes, and (ii) specially designed images can be more effective than textbook images in helping students overcome typical misconceptions about seasons, such as the distance misconception. In the present study, we aim to investigate the interaction between the two approaches to teaching seasonal change. The research questions that guided our study were: RQ1) *To what extent does a laboratory activity improve students' conceptions of seasonal change when different types of images are used?* RQ2) *Does the interaction between a laboratory activity and the use of different types of images have a significant effect on students' conceptions of seasonal change?*

2. Methods

To answer our research questions, we adopted a 2x3 experimental design: we randomly assigned

337 ninth grade students to “laboratory” (N = 170) and “no laboratory” (N = 167) conditions, while both groups received instruction under one of the three conditions: textbook images and text (N = 56 and N = 60, respectively); teaching booklets with specially designed images and text (N = 55 and N = 54); only text with no images (N = 59 and N = 53). The students had not been taught about seasonal changes before the intervention, which took place during curricular hours.

In the laboratory condition, the students first investigated the dependence of the flow of a radiation hitting a surface at a fixed distance from the source on the inclination between the normal to the incidence surface and the direction of the radiation. Then, they investigated how the flow varied when the surface is kept orthogonal to the direction of the incident radiation, and the distance between the source and the surface changes. More details are reported in [3].

Specially designed images featured a circular Earth’s orbit and emphasized the constant direction of the Earth’s axis during the motion. Moreover, they did not include arrows to indicate the rotation and revolution of the Earth and other information not relevant for the phenomenon (e.g., segments that connect the Earth to the Sun). The images also avoided the use of unnecessary text as, for instance, the reference to aphelion and perihelion. More details are reported in [4].

As research instruments, we used a draw-and-explain task and a brief questionnaire featuring two ordered multiple choice and 6 true/false items. The brief questionnaire was given also as a pre-test for baseline comparison between the six groups.

Students’ drawings and explanations were initially categorized using the rubrics reported in [4]. Inter-rater reliability was evaluated through Cohen’s kappa obtaining satisfactory values: 0.8 for drawings and 0.9 for explanations. We then collapsed the responses into three general categories: naïve; partial; correct. Finally, we combined the obtained categorial variables into a single factor by means of Multiple Correspondence Analysis (MCA). The first extracted factor explained 74% of the variance in the data. Positive values of the extracted factor correspond to a correct explanation and a correct drawing, while negative values correspond to an incorrect explanation and a naïve drawing.

True/false items were given 0.5 point for a correct response, while ordered multiple choice items were given 1 point when selecting the partially correct answer choice and 2 points for choosing the correct answer choice. For both type of items, an incorrect answer was given 0 point. The maximum score was 7.

To confirm that the six randomly formed groups had similar initial knowledge about the seasons, we performed a one-way analysis of variance (ANOVA) on the questionnaire score in the pre-test.

Then, to inspect the effects of the interaction between the two approaches, we first performed a 2-way ANOVA with the score in the first factor extracted from the MCA as the dependent variable and the laboratory and images conditions as independent variables. Then, we performed a 2-way ANOVA using the questionnaire score in the post-test as dependent variable.

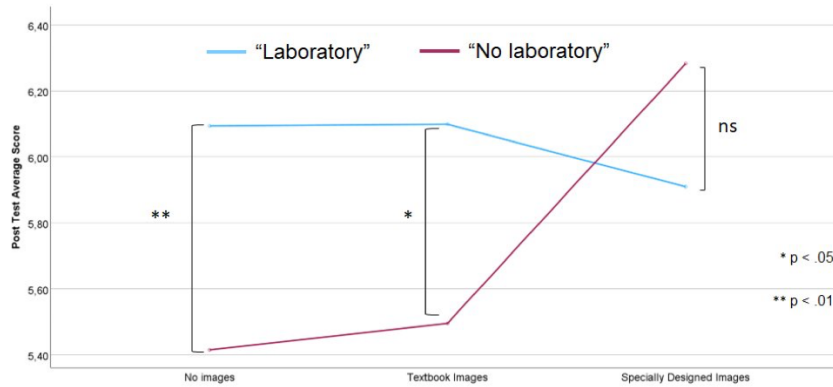


Figure 1: Students' post-test questionnaire average scores for the 3 x 2 conditions of the study.

3. Results

As expected, results of the ANOVA on the pre-test questionnaire scores shows no significant differences between the six groups, $F(5, 331) = .573, p = .721$.

When performing the 2-way ANOVA on the post-test questionnaire (Figure 1), we found a significant main effect of the laboratory activities, $F(1, 331) = 4.964, p < .05$ and of the interaction between the two conditions, $F(2, 331) = 9.491, p < .01$. The images condition does not have a significant main effect on the post-test score, $F(2, 331) = 2.466, p = .086$. However, simple effects analysis reveals that for the "text-book images condition" and for the "no images" condition, the differences between the post-test score of the students who performed the laboratory activity and that of the students who did not performed the laboratory activity are statistically significant, with students in the "laboratory" condition that outperformed the students in the "no laboratory" condition, $F_{\text{textbook images}}(1, 331) = 6.786, p < .05$; $F_{\text{no images}}(1, 331) = 8.289, p < .01$, respectively. Contrarily, for the students in the "innovative images" condition, such difference is not statistically significant, $F_{\text{innovati images}}(2, 331) = 2.452, p = .118$. We also note that students in the "no laboratory" condition performed better than students in the "laboratory" condition. Correspondingly, for the "laboratory" condition, simple effects analysis shows no differences between the groups who used different types of images, $F_{\text{images}}(2, 331) = 0.418, p = .659$, while for the "no laboratory" condition, the differences across the groups are statistically significant, $F_{\text{images}}(2, 331) = 8.076, p < .001$, due to the statistically higher score of the students in the "innovate images" condition ($p < .01$).

When performing the 2-way ANOVA on the factorial score that combines the responses in the draw-and-explain task (Figure 2), we found a significant main effect of the laboratory activities, $F(1, 331) = 53.685, p < .001$, of the type of images, $F(2, 331) = 3.747, p < .05$ and of the interaction between the two conditions, $F(2, 331) = 6.789, p < .01$. Simple effects analysis shows that students in the "laboratory" condition outperformed students in the "no laboratory" condition in both the "textbook images" and "no images" conditions, $F_{\text{textbook images}}(1, 331) = 13.005, p < .001$; $F_{\text{no images}}(1, 331) = 50.562, p < .001$, respectively, while the difference in the case of the "innovative image" condition is only slightly significant, $F_{\text{innovati images}}(1, 331) = 3.963, p < 0.05$. Note however, that in the "laboratory" condition, the difference due to the use of images is not statistically significant, $F_{\text{lab}}(2, 331) = 1.039, p = .355$, while for the "no laboratory" condition, the differences across the groups are statistically significant, $F_{\text{no lab}}(2, 331) = 9.224, p < .001$, due, also in this case, to the statistically higher score of the students in the "innovate images"

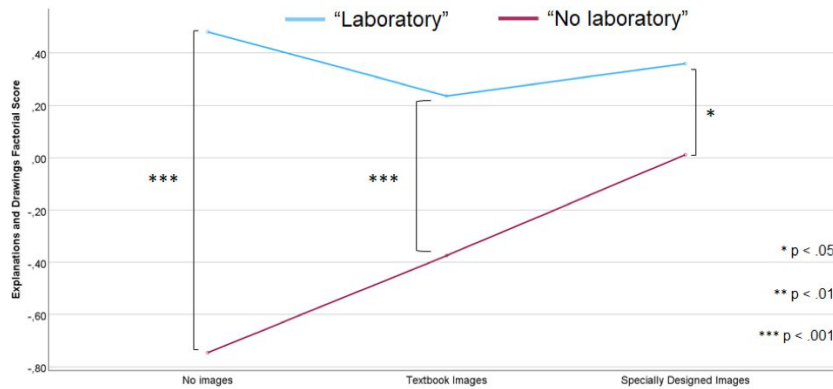


Figure 2: Students' post-test factorial average score in the draw-and-explain task for the 3 x 2 conditions of the study.

condition ($p < .001$).

4. Discussion and conclusions

Concerning the first research question, collected evidence supports the conclusion that the students in the "laboratory" condition outperformed students in the "no laboratory" condition, independently of the type of used image ("textbook images"; "specially designed images"; "no images"). This result suggests that the proposed laboratory activity is predominant with respect to the support provided by images in the teaching of seasonal changes. However, concerning the second research question, we found that when students in the "no laboratory" condition were taught with the specially designed images, their performance did not significantly differ from the performance of the students in "laboratory" condition. Moreover, we found that in the "no laboratory condition", students who used the specially designed images outperformed the students that used the textbook images or no images at all. Thus, the present study confirms the results of our previous studies [3-4].

Our study has two main implications. First, practical activities are effective to address well known misconceptions in astronomy. Therefore, more efforts should be put to implement it in classroom contexts, at least as an interactive demonstration or by integrating it with the use of suitable computer-based simulations. Second, specially designed images can effectively improve students' conceptions especially in teaching contexts in which practical activities cannot be carried out. Overall, this study could be fruitfully extended to other astronomy phenomena, e.g., Moon phases, for which literature suggests a relevant influence of textbook images on students' conceptions.

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Using Stories to Assess College Students' Ideas About Astronomy

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

Collaborators: Andrea Ragonese, The Pennsylvania State University, USA

We investigated how college education majors consider 'who does astronomy' and 'what counts as doing astronomy' during an introductory astronomy course. As a final project, students wrote children's storybooks. Thematic analysis of students' storybooks suggests that many students recognize the importance of showing that astronomy is done by people of color, women, and children. Many students also demonstrated the dynamic nature of science through characters engaged in the practices of science. However, we also noted limitations in how some students portrayed astronomy, such as focusing on astronomy as learning facts and limiting the protagonist's agency. The storybook project helped us understand how students can apply an anti-deficit perspective through the creation of classroom media.



Talk link: <https://youtu.be/KmrNLHpfo5I>

We examined how engagement in an introductory astronomy course supported college students, studying to become teachers, in applying an anti-deficit perspective towards astronomy. Each student wrote a children's storybook as the final course project. We chose this project because of the key role storybooks play in children's science instruction (e.g., Pringle & Lamme, 2005). Writing a storybook also served as an opportunity for us to assess students' thinking about the nature of astronomy. In a prior study, this method — preservice teachers writing their own children's books — helped us understand the depth of their understanding of the practices of science in astronomy investigations (Plummer et al., 2021). Our study was guided by the following questions: In what ways do preservice teachers write astronomy storybooks that identify diverse peoples with expertise, knowledge, and ownership in astronomy? and, convey astronomy as embedded in culture and enacted through practice? and, recognize the importance of place in how astronomy is practiced? Answering these questions demonstrates the potential and challenges preservice teachers face in communicating the inclusivity of astronomy and the dynamic nature of science.

Framework for Anti-Deficit Perspectives in Science Education

Our work uses an anti-deficit perspective by flipping our perspective from asking what learners are missing to identifying what they bring with them (Mejia et al., 2018). Stereotypes concerning who can do science and what counts as science continue to influence what science is taught and how it is taught in K-12 educations. We seek to help students develop a more nuanced

understanding of: *Who Does Science?* It is important that children see themselves reflected in classroom media in order to visualize themselves succeeding in sciences. Further, children need to see role models from minoritized backgrounds in books, videos, and other media in order to develop positive associations that all people can be successful in science (Husband, 2018). *What Counts as Doing Science?* We pursue a dynamic vision of science; science changes as we gather more evidence and discover new ways to think about the world. Thus, we focus on how science is a process rather than the outputs of science (NRC, 2012). Children need to see the personal, cultural, and historical context of science being shared, rather than viewing science as neutral or objective. The cultural element of doing science influences the questions we investigate, the methods we implement, and interpretations we make from evidence (Bang et al., 2018; Warren et al., 2020). *How Does Place Shape Science?* Our understanding of science is shaped by specific cultural, ecological, and geographical contexts. How students learn is tied to their understanding of the relationship between science and those place-based contexts. Johnson (2012) argues that “placelessness” is a way that Western science and scientists disconnects from Indigenous ways of learning and knowing the natural world.

Methods

Setting and Participants

Study participants (N=24) were students taking an introductory course on astronomy designed for teachers at a large public university in the northeastern United States. Most students (88%) were in their 1st or 2nd year of college and were majoring in elementary education (83%). As a final project, the students wrote a children’s astronomy storybook. Initially, students critiqued a published children’s astronomy storybook with a small group of peers (all books focused on characters of minoritized backgrounds). Midway through the semester, each student submitted a proposal describing their book to their professors. Students were asked to author narratives featuring human characters engaged with astronomy. In writing their storybook, students were asked to demonstrate their understanding of *What counts as doing astronomy? Who does astronomy?* and *Where is astronomy done?* They also answered these questions on the final “goals page”.

Data Collection and Analysis

Participants wrote their storybooks using storyjumper.com. Storybooks had an average length of 26.2 pages (SD = 4.6). We used thematic analysis for our analysis (Maguire & Delahunt, 2017). We used a theoretical, rather than inductive, process to generate initial codes in that we were guided by our questions and prior literature on children’s storybooks. Both authors coded and reviewed all coding, using an iterative process to develop new codes, then apply these to all books over time. Next, we constructed themes by looking for patterns in the codes that revealed something interesting with respect to our research questions. Finally, examined the relationship between themes using a thematic map (Maguire & Delahunt, 2017).

Findings

Who does astronomy?

The students frequently wrote storybooks featuring main characters from races and genders beyond that traditionally shown in children’s books: white men doing science. Students communicated that astronomy can be done by main character(s) who were children (n=22), girls and women (n=15), and people of color (n=8). Stories also featured characters from multiple races

and ethnicities doing astronomy (n=4) and families engaged in astronomy together (n=8). One limitation we observed was that some students showed a disconnect between their expressed goal that “anyone” can do astronomy and what they represented in their books. For example, some of these students still only depicted white main characters doing astronomy (n=7) while others undercut the message by showing characters that lacked agency in engagement with astronomy (n=7).

What counts as doing astronomy?

Some suggested that ‘what counts as astronomy’ is working as an astronaut or going into space in a spacecraft (n=9). We also found that students equated doing astronomy with learning about general astronomy facts or astronomy topics (e.g., the moon, space travel) (n=16). These themes contrast with our finding that students depicted characters engaged with science practices. Storybooks featured characters engaged in scientific observation (n=16) or using scientific tools to aid in observation (e.g., telescopes, cameras, or phones) (n=9). Storybooks also featured characters drawing or journaling about their observations (n=5).

Where is astronomy done?

Students depicted characters engaged with astronomy in familiar places, such as: outside (e.g., in the backyard or at the park) (n=14), classrooms (n=10), in space (n=6), and at home (n=5). On their goals page, many students expressed a belief that astronomy can be done “anywhere” (n=13). While the places they identified are relevant to astronomy, we need to do more analysis to better understand what these students think about how astronomical knowledge is shaped by the place it was created.

Conclusion

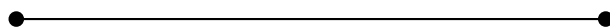
The storybook project provided us with a window into our students thinking about astronomy and how it should be communicated to young children. This revealed strengths in how these future teachers chose to portray astronomy for children. We found that many of their books featured main characters from minoritized backgrounds doing astronomy. This is important because children’s storybooks play a significant role in providing children with an image of who does science. They can provide children with a positive representation of race, culture, and gender, supporting children’s identity with science (AACAP, 2016; Husband, 2018; Pew Research Center, 2015). Second, many students’ books showed the dynamic nature of science through characters use of science practices. In contrast, many published children’s science books are limited in how they show characters using practices of science and the nature of science (Kelly, 2018; Plummer & Allen, 2023). These future teachers’ inclusion of science practices in their books may indicate that they will consider selecting books that depict the dynamic nature of science for their future classrooms. We also identified areas where students needed more support in their use of an anti-racist lens on science. Some students limited the child protagonist’s agency in science by depicting adult characters providing answers or solving problems for them. This traditional view of science was also reflected in the books that emphasized astronomy through traditional school-based settings and methods (e.g., learning astronomy facts). Finally, we noted other limitations in character diversity from the books. For example, similar to published children’s books, there was limited depiction of characters with disabilities; we only identified one main character (a girl in a wheelchair) and one supporting character (a girl who is blind) with disabilities.

Recommendations for K-12 Science Education

Our focus on *who does astronomy? what counts as doing astronomy? and how does place shape astronomy?* can be applied to K-12 science education. Teachers could use these guiding questions to help children attend to who is represented in the books and media in their classroom, allowing the students to become critical consumers of their own science media. We also encourage teachers to allow students to tell their own astronomy stories. These stories may help children express their own interests in science and visualize themselves as scientists.

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Astronomy Literacy Test (ALT): A Proposal Diagnostic Test for Astronomy Literacy

Speaker: Prathmesh Jadhav, Savitribai Phule Pune University, Pune, Maharashtra, India

Collaborators: Ilídio André Costa, (Santa Bárbara School Cluster, Porto Planetarium –Ciência Viva Center, Institute of Astrophysics and Space Science – Porto University, Portugal), Ranjini N (GSI college, Mysore, India)

There are several astronomy diagnostic tests based on national syllabus and targeting specific audiences. However, they are limited by their diagnostic scope as they do not allow the participant to learn more about the field. Hence, we built the Astronomy Literacy Test (ALT). This test has 3 goals: Diagnose astronomy literacy, raise astronomy awareness, and make it valuable for any country or respondent. ALT is based on the global document endorsed by IAU: The Big ideas in Astronomy. It is an interactive and self-learning test. After submitting the test, correct answers are displayed, along with the links to explore the concepts. With ALT's 1st version, we aim to collect inputs to turn it into a global tool to assess astronomy literacy and design outreach activities, courses, and citizen science projects.



Talk link: <https://youtu.be/noJaPXCcpuM>

Astronomy is a complex and challenging subject, but it is also one of the most accessible and engaging sciences. By learning about astronomy, people can develop a deeper understanding of the scientific methods and how science is used to explore the world around us. Astronomy can also help people to develop critical thinking skills, as they learn to assess different theories and explanations of astronomical phenomena.

It is very important to educate people about astronomy and also assess how much a common citizen knows about this vast subject. What if we could educate and assess simultaneously? We propose the Astronomy Literacy Test (ALT) an assessment tool and an education tool through which we can achieve both. This is a test based on 'Big Ideas in Astronomy', a document which proposes a definition for astronomy literacy. ALT is a test designed to test astronomy literacy for a wide range of people who may be of different age groups, countries, and educational backgrounds. Anyone can attempt the test.

This document establishes the "11 Big Ideas" and supporting concepts that all citizens of our planet should know about astronomy. By keeping this document as a reference, we started out

to create an assessment tool for these Big Ideas.

ALT is a multiple-choice test. Our goal is to make the test interesting and engaging to undertake, so it is being designed with a lot of images to increase curiosity in the participants. We plan to include at least one question from each of the Big Ideas in the document. After carefully going through the document we selected some topics which are very relevant for the present timeline of astronomy. With each question the participants can learn about the concepts included in the Big Ideas document.

This test also has a self-learning component in it. Once a participant submits the test, they will have immediate access to correct answers to the questions and hyperlinks related to the topic will be displayed. The participant can learn more from the given links. The test will be put out in the form of a survey on an online platform.

Through the first version of the test, we aim to collect inputs and further use it to know the status of astronomy literacy and design astronomy courses and outreach activities. We also plan to include the concept of citizen science so that more people can have access to real science data. Overall, ALT can be a valuable tool for improving the quality of astronomy education and research.

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Teaching the Seasons by Analyzing Data and Modelling

Speaker: Pierre Chasternay, Université du Québec à Montréal, Canada

Collaborators: Emmanuel Ahr, Mohamed Amine Mahhou & Simon A. Bélanger, Université Du Québec à Montréal, Canada

The seasons is a concept in astronomy that is particularly difficult to understand. We propose to teach the seasons by prompting students to analyse day-to-day data (sunrise and sunset times and azimuth, height of the Sun at noon, length of day, etc.) for their location, and compare it with the same data for a location positioned at the same latitude in the Southern hemisphere. By modelling the reasons for seasons using concrete objects (a Styrofoam ball and a lamp), students will connect the apparent motion of the Sun with the inclination of Earth's axis of rotation to the plane of the ecliptic. We will present the results of an experiment conducted with preservice high school teachers enrolled in an astronomy teaching course, using a Seasons Concept Inventory as pre- and post-test.



Talk link: <https://youtu.be/xEEfRBFdz94>

How do astronomers do astronomy? Based on the history and epistemology of knowledge construction in astronomy, we propose the knowledge-building cycle in astronomy (Fig. 1) to represent the way astronomers do their work. Astronomers start with a question and tentative explanations (hypotheses), before collecting data and analyzing it, searching for correlations, cycles, systematicity, and invariants hidden in the observations. Results of this analysis lead astronomers to build a model, which is a simplified version of the astronomical system under study. Since astronomers don't have direct access to astronomical systems, the model becomes the only tool with which astronomers can control variables to try to understand how the system works. Astronomers then make predictions, based on the model, and communicate their findings to the scientific community, which leads to new questions and a new cycle.

This knowledge-building cycle can be transposed in the classroom, so that students can do astronomy like astronomers do (Chasternay et al., 2023) and use it, for example, to learn about the Earth's seasons. The seasons is an astronomical concept present in most OECD K-12 curricula (Salimpour et al., 2020), but it is also one of the most difficult to learn in the classroom (Plummer, 2012). To understand the mechanism of seasonal change, as with any astronomical concept, students first need to become familiar with the phenomenon as seen from a geocentric point of view (Plummer, 2017), but they also need to be able to switch perspective between the geocentric and the space-based, or allocentric, point of view (see Chasternay, 2016; Heywood et al., 2013; Subramaniam & Padalkar, 2009). According to Sadler (1992), "without the ability to

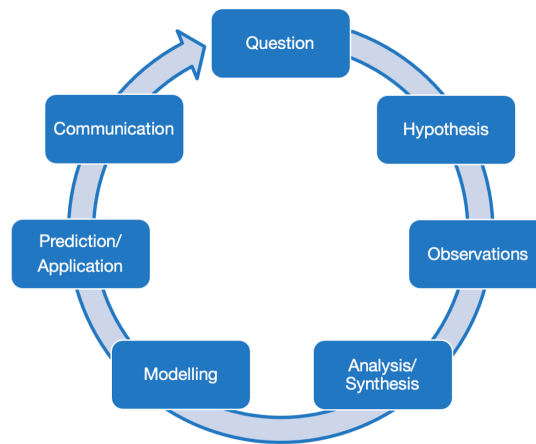


Figure 1: The knowledge-building cycle in astronomy. Source: PC.

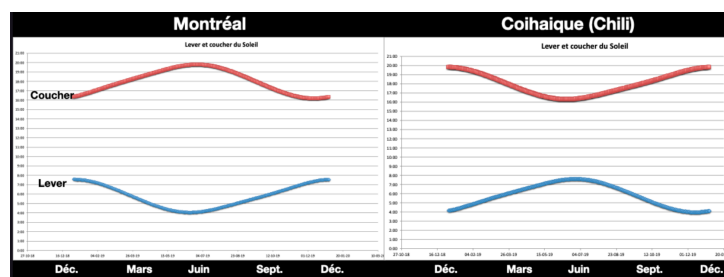


Figure 2: Graphs comparing sunrise (blue curves) and sunset (red curves) times for one year between Montréal and Coihaique. Source: PC.

imagine what objects look like from different perspectives, students will find many astronomical concepts virtually impossible to learn". (p. 103) Fortunately, students don't have to imagine the space-based perspective on astronomical systems, since concrete models in the classroom can support understanding by facilitating perspective-taking on these systems (Plummer et al., 2016).

If we apply the knowledge-building cycle in astronomy to the teaching of seasons, we realize that it is almost impossible for students to gather data from direct observations, as the phenomenon changes almost imperceptibly from one day to the next and takes a whole year to unfold. To overcome this difficulty, we propose to teach the seasons by inviting students to analyze daily data (times and azimuths of sunrise and sunset, height of the Sun at midday, length of day, etc.) provided to them for their location and to compare it with the same data for a location at the same latitude in the other hemisphere. In the present research, we provided students with Sun's ephemeris for one year for Montréal (Canada) and Coihaique (Chile); both cities are located at the same longitude and latitude, but in different hemispheres. Students were then led to create graphs to compare Sun ephemeris for both location (Fig. 2).

By answering a series of probing questions about the data analysed for the two locations and the different graphs they created, students were led to realize that the seasons are reversed from one hemisphere to the other and that seasonal changes are mainly due to the height of the sun in the sky and the length of day. Finally, by modelling the seasons using concrete objects (a polystyrene ball with two push pins representing both locations, and a lamp representing the Sun, Fig. 3), students made the link between the apparent movement of the Sun in each

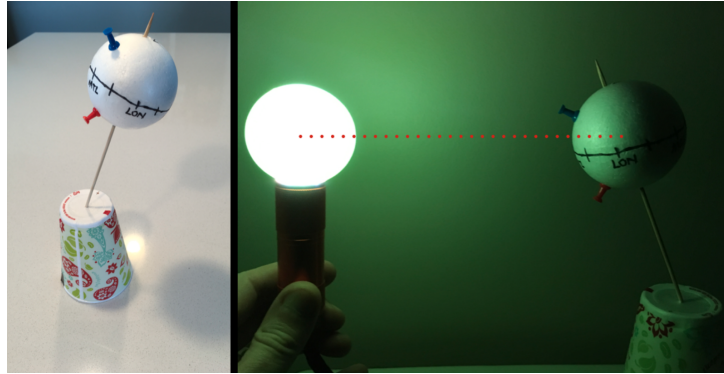


Figure 3: A simple concrete model of the Earth and Sun to explore the reasons for seasons. Note the inclination of the axis of rotation (at about 23 degrees) and the two push pins marking the locations of Montréal (blue) and Coihaique (red). Source: PC.

hemisphere (geocentric view) and the inclination of the Earth's axis of rotation in relation to the plane of the ecliptic (allocentric view). Students were encouraged to share explanations and compare their understanding of the phenomenon with each other and to explore seasonal changes on other planets of the solar system based on the inclination of their polar axis, for example Mercury (0 degree) and Uranus (98 degrees).

In order to evaluate the effectiveness of this approach to teach the seasons, we enrolled 37 pre-service high school teachers in an astronomy methods course (22 males, 15 females, Mean age = 28.7y, SD = 9.7y), of whom 25 completed both pre- and post-test at 2-month interval. Our instrument, the Reasons for Seasons Concept Inventory (RSCI), is a 22-question, multiple-choice questionnaire with items drawn from six valid concept inventories in astronomy (Hufnagel, 2002; LoPresto & Murrell, 2011; Sadler, 1992; 1998; Sadler et al., 2010; Slater, 2014; Zeilik, 2002). Since the distribution of scores in the post-test was not normal, we used a Wilcoxon Signed-Ranks Test (WSRT) for related samples (N = 25) run in SPSS (v26.0) to compare pre- and post-test students' scores. The WSRT is similar to the dependent t-test when normality cannot be assumed. The result indicated that post-test scores on the RSCI were statistically higher (Median = 18) than pretest scores (Median = 13): $Z = 4.331$, $p < .001$. Effect size is considered large at $r = 0.87$ (Cohen, 1988; Sawilowsky, 2009).

There are several limitations to our study, which is a first iteration in a process of development research (Shavelson et al., 2003). First, we used a small sample (not randomized), and we didn't have a control group. Hence, generalization is hazardous. Part of the learning gain could be attributed to maturation or out-of-school sources of information (not controlled). Finally, we were not able to conduct a delayed post-test before the end of semester to measure long-term retention. Future studies will try to overcome these shortcomings and adapt the teaching sequence for middle and high school students.

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POSTER CONTRIBUTIONS

Qualitatively Assessing an Online Research Course for Astronomy Majors

Presenter: Skylar Grayson, Arizona State University, USA

Research experiences as an undergraduate are one area where online programs are trailing behind traditional degrees, due to the difficulty of providing experiences to remote students. To remedy this, we have developed an online Course-Based Undergraduate Research Experience (CURE) for students in Arizona State University's online Astronomical and Planetary Sciences degree. Here, we present the preliminary qualitative results from interviews administered to twelve students. We find that a majority of the interviewed students express an increased sense of belonging in astronomy and the school, improved science identity, and greater confidence in their research abilities. This work is part of a broader mixed-methods project analyzing the benefits of this CURE over the course of three years.



Poster link: <https://doi.org/10.5281/zenodo.10443560>

Background: Course-Based Undergraduate Research Experiences (CUREs) provide students access to authentic research, which has been shown to have a myriad of positive effects. These include improved data analysis skills, better understanding of scientific processes and thinking [1], an increase in self-efficacy [2], an increase in perceived competence and confidence [3], and higher retention rates [4]. However, as online education grows in popularity, online students do not have the same opportunities to participate in CUREs as their in-person counterparts. To remedy this, we offer an Exoplanet Research Experience online CURE to students in Arizona State University's Astronomical and Planetary Sciences (APS) degree. The APS degree is undertaken by a diverse set of students, with 12% first generation, 36% non-white, 33% Pell-Eligible, and an average age of 29 as of Spring 2023. The diversity of this student population demonstrates the ability of online degrees to cater to non-traditional learners, and ensuring that the quality of the online curriculum is comparable to in-person instruction is of paramount importance. Our CURE consists of four units to help students understand transit photometry, learn to reduce light curves, perform reductions on a new target, and write up their results into a paper that is submitted to publication. The only prerequisite is an introductory level astronomy course, and the CURE is designed as an entry to conducting scientific research.

Methods: To evaluate the effectiveness of the CURE we assessed multiple outcomes that have been shown to be associated with CUREs, as designated by the “large CURE model” from Corwin et al., 2016 [5]. In particular, we assessed student gains in self-efficacy, science identity, sense of belonging (both at ASU and in astronomy as a whole) and project ownership. We utilized a mixed-method study, but focus here on the qualitative analyses and results. In order to qualitatively assess these outcomes, we administered interviews to a volunteer subset of students who took the course in Fall 2022 and Spring 2023. The 26-question interview asks about the outcomes above as well as certain factors that may lead to gains or lack thereof in these outcomes, such as relationships with other students and instructors, course design, and prior experience. Student interviews were analyzed using a codebook with 77 codes split into eleven sections to ease the analysis and connection of interview responses with quantitative survey questions. The eleven key topics were as follows: Sense of Belonging, Confidence, Persistence in Research, Science Identity, Interpersonal Relationships, Diversity, Course Design, Agency, Benefits of CUREs, Overall Course Gains, and Connection with ASU. We determined the inter-rater reliability of this codebook following the Fall 2022 semester using a simple proportion agreement statistic. As the initial agreement was poor, we took on a negotiated agreement approach, modifying 20 of the 77 code names and definitions to the mutual satisfaction of two coders. The inter-rater reliability of the reformulated codebook was then calculated to be above a predetermined threshold of 80% and was used to code all student interviews.

Results: Twelve students were interviewed in the first year of the CURE being offered, with 7 interviewees taking it in Fall 2022 and 5 in Spring 2023. The qualitative results from these interviews suggested improvement across all the effective outcomes listed above. Regarding self-efficacy, all 12 students stated that their confidence in using research tools and ideas increased. As one student shared, *“I feel like this course really helped break down the process [of research] for me. It is not as intimidating a process as it was to me when I started the class.”* Students also shared how their general confidence in STEM fields increased thanks to the CURE: *“I’ve had some struggles over the years with certain applied mathematics, calculus... specific chemistry courses... This course had the opposite effect. It showed that if I’m able to apply skill and interest and methodology in certain areas, that I really do have the passion, drive, and competency for science.”*

This course also impacted the students’ science identity, with 10 interviewees sharing that they felt like a scientist after the course, and 9 students stating that taking this CURE changed their perception of what it means to be a scientist. A large element of that change was a better understanding of the collaborative elements in science, as one student explained: *“We used to think that scientists, you know, went into a lab as an individual and came out with great ideas and wrote those ideas down and delivered them to the world. But even if that were a reality at one point, it is not today. Today it is extraordinarily important to work collaboratively.”* Sense of belonging was also positively impacted, with all 12 students feeling they belonged more in astronomy after the CURE, and 8 of the 12 feeling more connected with ASU. Finally, project ownership was a large factor amongst the students, with 11 interviewees feeling as if the work they were doing was meaningful and that they were empowered to take leadership in the course.

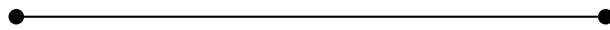
These results were generally in line with the quantitative results in the form of pre- and post-primarily Likert-style surveys administered to the students. These results found significant improvement in self-efficacy and science identity with large effect sizes. The changes in sense of belonging were smaller, which could be attributed to students entering the course with high senses of belonging, perhaps attributed to taking a previous research course, and the general

problems that arise in self-reported data. In general, the qualitative results suggested larger gains than what was reflected in the quantitative component.

Conclusions: Overall, student interviews suggested that this CURE was a positive experience that led to several key effective outcomes. Preliminary results show quantitative improvement in self-efficacy and science identity, supported by qualitative data which also suggests similar improvements in sense of belonging. In order to better understand student experiences and why qualitative and quantitative data disagrees, this CURE will continue to be offered and a larger study assessing these outcomes will take place after 6 semesters.

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The Effect of Adaptive Technology on Quantitative Literacy Within the Online Astronomy Classroom

Presenter: Grace Beall, Arizona State University, USA

Quantitative Literacy (QL), the ability to understand and accurately use numbers, is pivotal when learning astronomy, as prior research shows it has a strong, positive correlation with a student's success in science courses. In this study, we measure students' QL levels pre- and post-completion of an online astrobiology course, outfitted with adaptive technology, to examine the effects of the technology on this skill set and overall course achievement. Adaptive technology provides students in the online environment with immediate, specific feedback as they answer questions and complete course material. Preliminary results suggest no significant change in students' QL levels and a significant, moderate, direct correlation between incoming QL and final grades.



Poster link: <https://doi.org/10.5281/zenodo.10443569>

Introductory astronomy courses are one of the most popular general-education science classes at the university level, and with online learning becoming increasingly prevalent over the past few decades, it is more important than ever that educators employ the most effective tools for the online, science learning environment. One such tool, adaptive technology, provides students in the online environment with immediate, specific feedback as they answer questions and complete course material. Quantitative Literacy (QL), the ability to understand and accurately use numbers, is also pivotal when learning astronomy, as prior research shows it has a strong, positive correlation with a student's success in science courses. In this study, we investigate the effects of adaptive learning technology on student's QL skills and final grades.

Habitable Worlds (HabWorlds) is a fully online, adaptive learning astrobiology course developed by ASU's Center for Education through Exploration (ETX). We explore the following research questions: 1. Is a student's incoming level of QL a significant predictor of their final grade in HabWorlds? 2. Do students have increased QL skill levels after completing HabWorlds? By looking at HabWorlds, we can see if an online course, outfitted with adaptive learning technology, is more successful than other online astronomy courses at bridging the gap in terms of overall course performance between students with lower initial QL skills and those with more developed QL skills.

Preliminary results suggest no significant change in students' QL levels pre- to post-completion of HabWorlds. However, initial evidence suggests that HabWorlds may improve students' skill and confidence with spreadsheet usage. Analysis of student spreadsheets from the course will provide further insight. Additional statistical analysis (e.g., regression) will be used to assess the predictive significance of incoming QL levels in relation to students' final grades earned, though initial results suggest a significant, moderate, positive correlation.



Designing an Evaluation Framework and Tool for Astronomy Content in School Textbooks

Presenter: Asmita Redij, Homi Bhabha Centre for Science Education (HBCSE-TIFR), V. N. Purav Marg, Mankhurd, Mumbai, India

For many students textbooks become the first contact point to kindle interest in a subject, like Astronomy explaining the day-to-day natural phenomena. Textbooks are instrumental in facilitating the scientific discourse in a classroom. Astronomy is introduced in middle school textbooks in many curricula across the world, most of which is limited to mere collections of facts and observed phenomena, creating little appreciation for the nature of science. This study involved designing a framework for evaluating the completeness of the astronomy-related content in school textbooks. In this talk, I will present the case of two curricula from India to bring out the rationale behind the design and introduce the General Textbook Evaluation Tool developed for Astronomy content.



Poster link: <https://doi.org/10.5281/zenodo.10443579>

Introduction:

Coveted reforms in science education demand incorporating an activity-based, hand-on, embedded learning method in the school over the traditional didactic teaching. There is emphasis on imbibing scientific processes rather than rote memorisation of the scientific content. Astronomy is making its way into the school curriculum as a 'Gateway science' [1], and textbooks serve as the first contact to kindle interest in the subject amongst students, some of whom might pursue it further. But in schools, referred textbooks determine the classroom discourse, and in many schools in India it could be the only resource available to the teacher. In this poster we discuss the need for this standard template to review astronomy content at school level. The proposed framework for evaluation is then implemented in a SpreadSheet-based tool for easy reviewing of the content. We present the findings from reviewing a curriculum followed by an educational board from Maharashtra, a state in India.

Framework for evaluation of astronomy content:

Both textual and visual representation play a vital role in enhancing students comprehension. Any new concept is introduced with some description, like the background, facts, definition. But the objective of the classroom interaction should be to go beyond the facts, allowing students to carry out observations or an activity which will help them understand the concept directly or through analogies and document it. The students should be encouraged to question

their observation/data, test them against the facts stated in the textbooks and discuss it. This discussion should further lead to finding the reason behind the observations or the data collected. The textual representation was evaluated along these parameters whether it is merely stating facts (Information) or whether it has elements of data taking (Observation) and reflecting on the data (Inquiry) and if the facts are further explained (Reasoning). Lastly, is there any effort to debunk the societal fears associated with the given concept (Myths).

For the visual representation, prescription by Vinisha et al., 2013 [2] was followed. First identified the type used, whether Photograph, Sketch, Map, Graph, Diagram. Then check if the visuals linked to the text, either by its explicit mention in the text or by placements. Third, check to see if the visual is appropriately labeled.

Spreadsheet-based Evaluation tool:

The astronomy content covered at school level are grouped as Earth, Moon, Sun, Solar System, Stars, Galaxy, Telescope, Space Mission. Each group has subgroups like the properties, motion, and phenomenon related to it. Like subgroups related to Moon include Motion of moon, Phases of Moon, Tides on Earth, Eclipse. Each of the subgroups has a list of key concepts associated with it. The Spreadsheet has one sheet for each group and the first three columns on each sheet have a list of Group, Subgroup, Concept. The reviewer has to manually review the textual and visual content for different parameters discussed in Evaluation Framework.

Review of a curriculum:

Sample and Methodology: Proposed framework was used to review the curriculum followed by the state of Maharashtra from western part of India. For this, both science and geography textbooks used for the age group of 10 to 15 yrs were reviewed. Mixed method approach was used with qualitative and quantitative analysis.

Finding: While topics related to Earth like (Day/Night cycle, Seasons, Latitude/Longitude) and Moon (Phases, Eclipse, Tides) were covered in detail, leaving enough room to appreciate every stage of the scientific inquiry, topics introduced at the higher grade like, Evolution of Stars, Galaxies, and Telescope were mostly informative. They either directly stated the reasons behind the concepts or used analogies in a few places to explain the process where direct observation was not possible. Topics covered under 'solar system' were mostly informative with fair scope for improvement. Text for 'Evolution of stars' used words like 'electron pressure' and 'neutron pressure' without explaining them. 70% of the textual representation related to astronomy is delivered only as information, while 11% of it directly jumps to give reasons. 16% makes students observe/inquire.

Photograph, Sketch, and Diagram are commonly used for visual representation. About 12% of the visual rep. were not linked to the text or not labeled properly. In most of the places, visuals were linked to the content only by placement or with caption only, without explaining how to read the visual in the text.

Outlook:

The proposed framework should enable a deeper manual reviewing of the astronomy related content at the school level, beyond its current presence in the curriculum. More details could be found on https://astro4edu.iucaa.in/research_projects.html#textbookAnalysis

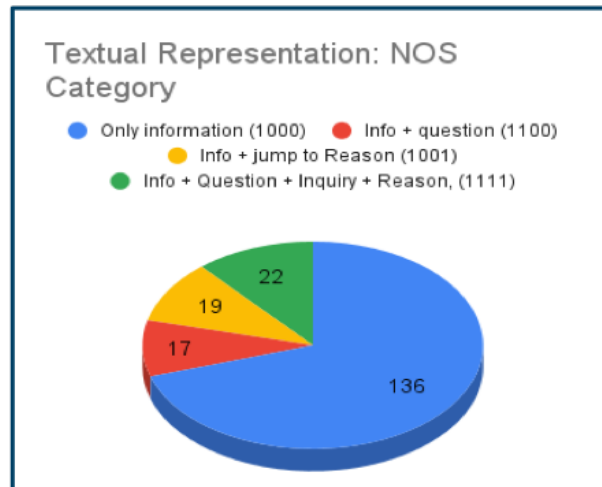


Figure 1: Levels of scientific inquiry.

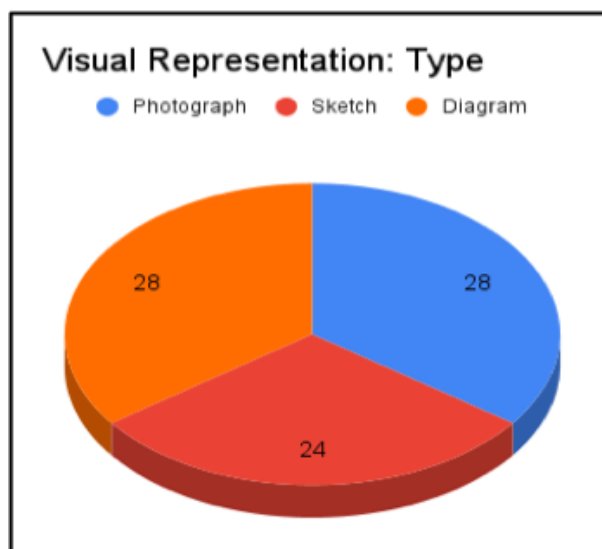


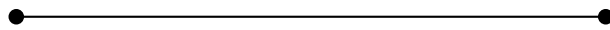
Figure 2: Types of visual representation used in School Textbooks.

Acknowledgement:

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Spatial Thinking in Astronomy Education: Bridging Gaps Through Linguistic and Cognitive Perspectives

Presenter: Saeed Jafari, Department of Linguistics, University of Kurdistan, Iran

In the realm of astronomy and physics, the paramount role of spatial thinking in exploration, comprehension, and transmission is firmly established. Understanding many astronomical phenomena requires spatial thinking skills, and astronomy is no exception. Functioning in our three-dimensional world in particular in astronomy requires spatial thinking about shapes, locations, and paths of objects along with relationships among objects and frames of reference (Newcombe, 2015). This talk shares the striking absence of spatial thinking and its potential impact on astronomy education, as well as examples of how to teach astronomical phenomena and celestial concepts in different linguistic and cultural contexts. Additionally, I will discuss the current state of spatial thinking in education.



Poster link: <https://doi.org/10.5281/zenodo.10443581>

Astronomy and physics are disciplines that heavily rely on spatial thinking for exploration, comprehension, and transmission of knowledge. This paper asserts that to understand various astronomical phenomena, individuals need to employ spatial thinking skills. This entails the

ability to conceptualize shapes, locations, paths of celestial objects, and understand the relationships between these objects, all within specific frames of reference — Newcombe and Shipley (2015).

Astronomy is a three-dimensional science, and to navigate this realm effectively, spatial thinking is indispensable. Therefore, it is imperative to integrate spatial thinking into astronomy education. However, an analysis of the current state of astronomy education reveals a striking absence of emphasis on spatial skills and the four tasks used to assess different spatial skills (Mental Rotation, Mental Transformation, Spatial Scaling, Perspective Taking).

The Impact of Omitting Spatial Thinking in Astronomy Education

The neglect of spatial thinking in astronomy education can have far-reaching consequences. Without a strong foundation in spatial thinking, students may struggle to grasp fundamental astronomical concepts and phenomena. This knowledge gap can hinder their interest and engagement in the subject, potentially discouraging them from pursuing further studies in astronomy, particularly physics topics.

Moreover, the less presence of spatial thinking instruction in teaching and learning astronomy may disproportionately affect students from diverse linguistic and cultural backgrounds. Different languages and cultures may have unique ways of expressing spatial relations, which can impact a student's ability to understand and communicate simple/complex astronomical notions. Hence, multiculturalism and language variety are important considerations in addressing the spatial thinking awareness and its performance in learning.

Recommendations for Integrating Spatial Thinking in Astronomy Education

To bridge the gap in astronomy education and enhance spatial thinking skills from linguistic and cognitive perspectives, I propose several practical strategies for science teachers in high schools, online teachers, formal/informal astronomy educators, and curriculum designers:

Multimodal Teaching: Incorporate a variety of teaching methods, such as visual aids, hands-on activities, and interactive simulations, to engage students in spatial thinking. For instance, using three-dimensional models or virtual reality tools can help students visualize celestial phenomena in a more tangible manner. (relative sizes of Earth, the Sun, and the Moon and the distances between these bodies)

Language Considerations: Recognize the linguistic and cultural diversity of students. Encourage the use of descriptive language that accommodates different linguistic backgrounds. Offer explanations in multiple languages when possible and create or find resources that facilitate cross-cultural understanding. (referred to local cultural astronomy and astronomical heritage)

Conceptual Frameworks: Develop clear and intuitive conceptual frameworks to aid students in grasping complex astronomical concepts. Use analogies and real-world examples to relate abstract astronomical ideas to everyday experiences. (celestial motions & gravity/density terms)

Collaborative Learning: Promote collaborative learning environments where students can discuss astronomical phenomena together. Group activities and discussions can enhance spatial

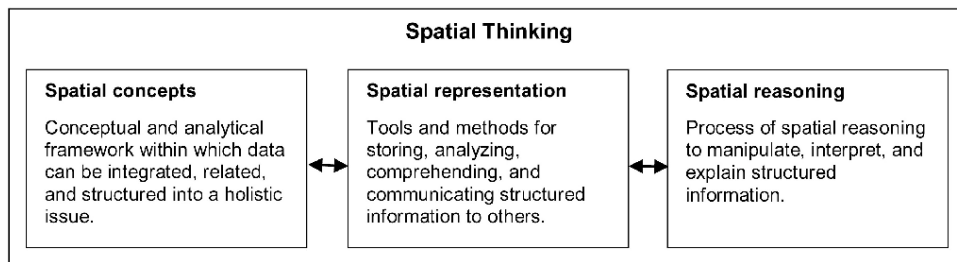


Figure 1: Description of spatial thinking as a constructive combination of three mutually reinforcing components, LEE and BEDNARZ (2006). Drawn by: Michel & Hof (2013).

thinking by allowing students to share and refine their understanding. (explanation of lunar phases).

Assessment Tools: Design assessment tools that evaluate spatial thinking skills, both within the context of astronomy and as a standalone skill. This will help astronomy educators identify areas where students may need supplementary assistance.

The Importance of Further Research to Improve Astronomy Learning

While these recommendations provide a valuable starting point, it is essential to underscore the significance of continued research in spatial thinking in astronomy education in general, particularly concerning endangerment and indigenous languages and diverse cultures. The existing body of knowledge is substantial, but ongoing investigation is necessary to refine and adapt teaching methods in astronomy and physics, taking into account varied educational contexts. Some areas that merit further research include:

Cultural Variability: A deeper exploration of how cultural and linguistic backgrounds impact spatial ability in learning astronomy is needed. Comparative Astronomy Education Research studies can shed light on effective strategies for accommodating diverse student populations.

Long-Term Impact: AER should focus on evaluating the long-term impact of spatial thinking instruction in teaching astronomy. Understanding how early exposure to it influences students' pursuit of STEM fields can inform educational policies and curricula.

Technology Integration: With the advancement of technology, research should investigate the effectiveness of integrating cutting-edge tools, such as augmented reality and artificial intelligence especially for the blind and deaf community, to enhance attention and perception skills in learning astronomical concepts.

Professional Development: Assess the cultural experience of educators and practitioners in professional development programs (like IAU OAE TTP), aimed at equipping them with the knowledge and skills necessary to teach spatial thinking effectively according to their local cultural contexts.

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DISCUSSION SUMMARY

The discussions in the Astronomy Education Research (AER) and Evaluation session delved into how we can advance research in astronomy education and where we should be focusing our efforts. The dialogue underscored the heavy reliance on quantitative methods over qualitative methods, likely due to researchers predominantly hailing from astrophysics backgrounds, where quantitative methods are more familiar. However, there appeared to be a consensus that methodology involving both quantitative and qualitative approaches, and diverse theoretical perspectives is essential for a comprehensive understanding. Speakers emphasised the value of interdisciplinary collaboration, encouraging collaboration with colleagues in social science and education departments.

There were discussions on how educational research is, by its very nature, challenging. There are myriad factors influencing people's learning, thus making it impossible to isolate them individually, or confine them to the classroom. Pierre Chastenay aptly expressed this complexity: "Describing a black hole is easy, describing a classroom is impossible". The relative infancy of AER was highlighted by Italo Testa, noting the predominant focus on students' understanding, misconceptions, attitudes, and ideas. However, he highlighted the new wave of focus in terms of cultural aspects of astronomy and young people's identities.

This was touched on in presentations from Julia Plummer and Moupiya Maji. They spoke about the importance of exploring students' ideas and understanding of what astronomy is, what counts as astronomy, and who does astronomy. This also prompted discussions about the importance of balancing storytelling with scientifically accurate information to ensure young people do not develop misconceptions.

While acknowledging the commendable work in astronomy education, there was recognition that the reported impact often remains anecdotal, and practitioners express a desire to be able to do more research into their educational practices. Speakers offered practical advice for aspiring researchers. Pierre Chastenay recommended starting with a small project and gradually expanding it. He also encouraged us to look at literature reviews to identify gaps and unanswered questions in research. Italo Testa stressed the importance of gaining an understanding of pedagogical approaches and learning theories to ensure we have a foundation for our research. Prathmesh Jadhav encouraged us to collaborate and work with others to share ideas and expertise. Members of the audience also encouraged collaboration with more experienced researchers when starting out.

Planetary Climate

Session organisers: Samantha Brown-Sevilla (OAE Heidelberg), Eduardo Penteadó (OAE Heidelberg), Nicolas B. Cowan (McGill University, Canada), Faustine Cantalloube (Laboratoire d'Astrophysique de Marseille, France; Astronomers for Planet Earth)

SESSION OVERVIEW

This year's special science topic session was dedicated to planetary climate. Given that climate change is one of the most pressing issues of our time, gaining a thorough understanding of how Earth's climate has evolved is crucial. This understanding can help us distinguishing between natural climate variations and those induced by human activities, as well as aiding in the development of effective strategies to mitigate and adapt to the effects of climate change. In addition, our knowledge of Earth's climate can help us better understand the climate in other planets. Having effective strategies to teach about these topics is essential, to address them from a constructive perspective that invites students to take action, rather than focusing on the negative aspects.

This session gave us an overview of the latest scientific research in the area of planetary climate. Due to the wide range of this topic, the session was divided into two sub-sessions: the first one addressed Earth's climate history and future projections; while the second one focused on climate beyond Earth, from other planets and moons in the Solar System to exoplanets. The topic of climate change was discussed in all sessions within the corresponding context.

Ten speakers shared their research and experiences on teaching about these topics, with talks including: an overview of the climate history of our planet, how climate change has already had an impact in doing astronomical research, the climate in the other terrestrial and giant planets in our Solar System, an alternative approach to teach about the effects of greenhouse gasses in different planets, cutting-edge research on life on Earth and beyond through the search of biomarkers in planet atmospheres, and the concept of habitability, as well as innovative tools and activities to teach about planetary climate and involve students in their local communities motivating them to take action.



Impacts of Climate Change on Astronomy

Speaker: Faustine Cantalloube, Laboratoire d'Astrophysique de Marseille (LAM),
France

Ongoing anthropogenic climate change is affecting weather patterns across the globe. Astronomical sites, home to world-class telescopes, are not spared from the fallout of climate change. This presentation summarizes the impacts of climate change on astronomical observations we can already observe today, as well as the trends expected at major sites. Four important parameters for astronomical observations are discussed: temperature, humidity, atmospheric turbulence, and wind speed. Other more significant threats, such as storms and forest fires, are also discussed. Finally, the social impact of climate change will certainly disrupt telescope operations due to lack of resources, restricted access or communication problems.



Talk link: <https://youtu.be/XPtAkYDXspo>

It has been now more than 30 years that most astronomical observatories around the world are collecting environmental data used to monitor the weather and optimize the telescope operations. This time range is by several times beyond the period of natural climate cycles affecting local weathers, such as El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), or the Antarctic Oscillations (AAO), which are the major influencers of the weather in the Chilean Andes hosting world-class observatories. Using these in-situ data, it is therefore possible to analyze the long trend evolution of the major weather parameters affecting the quality of astronomical observations, in the light of the ongoing anthropogenic climate change. In this communication, we focus on observatories hosting telescopes working in the visible and infrared. In this context, we explored the evolution of the four following parameters: (1) surface temperature, (2) humidity, (3) ground layer turbulence, and (4) high-speed winds turbulence.

On top of the in-situ data, we have access to public reanalysis data, which are reconstructed climate variables at a high cadence and spatial resolution, ranging from the last century to today. This reconstruction is made by assimilating any available data worldwide (from satellites, balloons launch, airports and any other weather stations) and running advanced modeling. For instance, the fifth generation ECMWF atmospheric reanalysis of the global climate, ERA5, covers

period from January 1950 to present at an hourly rate and within a 30km horizontal grid, from the ground up to 80km altitude (with 137 levels).

At last, we can also explore global climate model projections that are predicting regional climate variables evolution under a given radiative forcing, such as the IPCC-defined socio-economical pathways (SSP). For instance, the PRIMAVERA project developed monthly predictions, from 2015 to 2050, at high spatial resolution (ranging from 18 to 50km) over 19 vertical pressure levels, under the 'worst case' SSP5-8.5 scenario.

To summarize the impact of climate change on astronomical observations in the visible/infrared domain, this communication provides an overview of the various quantitative results published over the last few years, as well as a qualitative discussion about the current and potential impacts of the environmental crises on astronomical observation activities.

1. Global warming: the temperature as an obvious driver

The increase of greenhouse gas concentration in the Earth atmosphere, which almost doubled since the pre-industrial era (1750-1850), entails a radiative forcing increasing the temperature of the troposphere (the lowest atmosphere layer where weather events take place) and therefore the global surface temperature. This elemental consequence, foreseen by Arrhenius in 1896 and observed then monitored since the 60's, led to a current increase of the global average surface temperature by about $1.2 \pm 0.2^\circ\text{C}$ (1.7°C over lands and 1.2°C over oceans, absorbing more heat) compared to the pre-industrial era[1].

The temperature series measured at the Paranal observatory (Chile) on the 3-m above the surface weather station since 1998, when the observatory was established (archival data since October 1984 were also retrieve by [2]), show a mean increase of $1.5 \pm 0.2^\circ\text{C}$, in agreement with the global trend. The year-to-year temperature is, on its side, correlated with the natural climate cycle influencing this region, in particular the ENSO and PDO, as shown by [2]. The re-analysis data from ERA5 are in agreement with this increasing trend, the increase being more prominent during the austral summer. The PRIMAVERA projections, crossed-checked with both the in-situ data and the ERA5 data, show an expected increase of the surface temperature at the Paranal observatory location of about 3°C ($0.54 \pm 0.04^\circ\text{C}$ per decade) in 2050[3]. Other projection from the CMIP6 ensemble show an average of 4°C temperature increase in 2100 but on a coarser spatial grid that doesn't take into account the detailed orography of the site[4].

One of the consequences of this warming could be an increase of the ground turbulence, provided that the heat transfer between hotter ground layer with colder air provokes higher convection. Another mild effect noticed applies to the dome cooling system that is set during the day to the expected temperature at sunset in order to avoid heat exchange when opening the dome before the observations. This cooling system at the Very Large Telescope is set to a maximum temperature of 16°C and we notice a higher occurrence of sunset temperature beyond this lower limit ($\sim 2\%$ increase per decade)[2,4]. Another consequence affecting astronomical observations, specifically in the mid-infrared, is the sky background: Earth surface radiates energy, to balance the energy received from the sun (by an average of $398.2\text{W}/\text{m}^2$), following a black-body spectral distribution. Using Wien law, a change from 16°C to 20°C would shift the maximum peak from $10.02\mu\text{m}$ to $9.88\mu\text{m}$, with a spectral energy density increase of about 6.6%.

Another wider consequence of global warming, is that hot and dry conditions under strong winds

noticeably promote wildfires and bushfires across the world[1]. The wildfires are more frequent, more intense, longer and therefore more damaging, particularly in western North America and Australia hosting numerous observatories. Indeed, more and more astronomical observatories were threatened by flames during the last two decades, such as Mont Stromlo in Australia (partially destroyed in 2003), Siding Spring in Australia (partially destroyed in 2013), Mount Graham in Arizona USA (severely threatened in 1996, 2004, 2017 and 2021), Lick observatory in California USA (severely threatened in 2020), Mauna Kea observatory (access closed in 2019), and the historical Mount Wilson observatory in California USA (severely threatened in 2009 and 2020). In addition to this direct threat, wildfires and bushfires create huge plumes of debris, smoke and ashes extending across several thousands of kilometers horizontally and a few tenth of kilometers vertically depending on the wind conditions. Members of the International Dark Sky Association, working in the dark sky reserve of the Rockport State Park (Utah, USA), measured the effect of the plume of the Dixie fire (the largest single wildfire in California ignited on mid-July 2021), whose source is located about 1000km away, on the sky quality in August 2021: the sky background emission increased by more than three magnitudes. By burning the biomass, wildfire plumes are themselves constituted of greenhouse gas such as CO₂, water vapor and other ozone precursors: this significantly affects the numerous absorption lines of the sky in the near and mid-infrared, becoming more featured and variables, therefore altering the quality of spectroscopic data. At last, the ensuing plumes, opacifying the atmosphere, are constituted of aerosols (such as the PM_{2.5}) and toxic gases (such as CO) affecting the air quality, endangering health and potentially contaminating crucial resources such as fresh water.

2. Humidity conditions

Anthropogenic global warming leads to an overall increase in water vapor and moisture transport throughout the troposphere[1]. However, local patterns are more complex to study, in particular in extremely dry places such as the Atacama Desert where many astronomical observatories are installed (the mean relative humidity at Paranal is of 15.2%, with lowest records of 3%). The water concentration in the atmosphere is responsible for many highly variable absorption features across the spectrum. For spectroscopy, the use of a standard star doubles the observing time so models based on radiative transfer under given weather and atmospheric concentrations are preferred. Therefore, the weather parameters should remain as stable as possible during the observation sequence. Both in-situ and re-analysis data show no detectable specific trend on either the precipitable water vapor (pwv) or relative humidity (RH)[2,3,4]. PRIMAVERA projections show a slight pwv increase by 0.17mmH₂O/decade. The consequential risk of high humidity in observatories are multiple: condensation, leaching, corrosion, high-voltage component damages.

Another consequence of the intensification of the global water cycle is the severity of wet and dry events, leading to more intense and frequent floods and droughts[1]. Severe floods can prevent access to the telescopes, especially in places where infrastructures are not adapted to such events, or interruption of communications (as in March 2015 at the Paranal Observatory).

3. Atmospheric turbulence

The atmospheric turbulence affects the quality of the observation by distorting the incoming light and therefore reducing the achievable spatial resolution, defined by the telescope aperture size. Atmospheric turbulence depends on two main contributors: the near-surface wind (a few meters above ground) and the high-altitude and high-speed wind (namely the jet stream at 12km a.s.l.). The surface seeing has been measured for decades at the Paranal site using turbulence

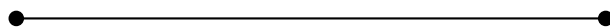
profilers: no clear trend has been detected for the last decades[2,4] and the predictions using PRIMAVERA data, also does not show any expected trend by 2050. The high-altitude and high-speed wind (namely the jet stream), also show no significant trend in both in-situ, re-analysis and projection data. Similar results are observed in the Northern Hemisphere at the Mauna Kea astronomy site[5].

IPCC latest report states that both subtropical jet streams are likely to strengthen, lift, and shift poleward under the worst-case scenario[1]. Better understanding the evolution of the jet stream above observatories requires further analysis. Also, even if there is limited information on the link between jet stream and storms in Hawaii, increased severity of storms is expected[1].

The quality of an astronomical site depends not only on its latitude, cloud cover and dryness, but also on its accessibility: it must be located in a place that is safe for observatory employees. Indeed, the operation of a telescope requires stable weather conditions, as well as access to resources such as energy, food, fresh water and basic health care. Climate change, and the ongoing environmental and social crises that follow, could alter our ability to conduct astronomical observations from the ground, surely more than just the meteorological aspects.

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The Polar Ice Sheets, Sea Level Rise, and Climate Change on Planet Earth

Speaker: Natalya Gomez, McGill University, Canada

Natalya Gomez and her research team work on understanding the physics of ice sheets, oceans, the solid Earth and climate change. Her talk focuses on understanding how the polar ice sheets in Greenland and Antarctica respond to climate change and cause global sea levels to rise and impact coastal areas around the world. She highlights the substantial amounts of ice loss and sea level rise that stand to be avoided by quickly transitioning away from fossil fuel burning, the need to prepare for changes to come in coastal areas, and the value of hope, connection and action to support resilience in the face of future climate change and move towards a more sustainable future.



Talk link: <https://youtu.be/N9YKHuLoBoc>



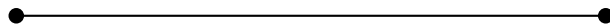
Global Climate Change and a Build-Up of a New Society

Speaker: Paulo Artaxo, University of São Paulo, Brazil

Since the Stockholm United Nations Conference on Human Environment in 1972, scientists have spoken about the effects of climate change. The consequences of this phenomenon are increasingly visible throughout the world. The last IPCC report revealed the impacts of increasing degrees of global warming in different regions of the world, from an increase in the average temperatures, to food production being affected by changed precipitation patterns. This is a wake-up call for us to build-up a new sustainable society.



Talk link: <https://youtu.be/iBSGH4RB4ns>



Effects of Greenhouse Gases on Earth, Venus, and Mars: An Undergraduate Level Tutorial

Speaker: Philip Nelson, University of Pennsylvania, USA

I present a discussion of the effect of increasing carbon dioxide on planetary climate, at a level suitable for insertion as a module into an upper-level Physics course. The treatment includes two key ingredients that are often missing from more elementary discussions, yet are amenable to analytic methods: First, that convection implies a dependence of surface temperature on the height of the outermost infrared-thick layer; and second, that increasing the level of CO_2 closes spectral windows of absorption. These themes are applicable not only to an industrializing Earth but also to our neighboring planets.



Talk link: <https://youtu.be/VHH8vS3ZJTM>

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Solar System Giant Planets

Speaker: Yamila Miguel, Leiden Observatory and The Netherlands Institute for Space Research (SRON), The Netherlands

In this presentation on ‘Solar System Giant Planets’, we embark on a journey through our current understanding of the atmospheres of the big giants in our Solar System: Jupiter, Saturn, Uranus and Neptune. We’ll explore the exciting space missions that have ventured into their realms and learn how the James Webb Space Telescope (JWST) and ground-based telescopes contribute vital information to our knowledge. In particular, we’ll talk about the fascinating findings from missions like Juno and Cassini, which have unraveled the mysteries behind the fast rotations of these giants and revealed the true shallowness of the Great Red Spot, among other findings. We’ll discover how we’ve probed the depths of their atmospheric bands and winds, unveiling their unique compositions. Join us as we unravel the secrets of their atmospheric and bulk compositions, shedding light on the remarkable journey of their formation and evolution. Along the way, we’ll touch upon the intriguing uncertainties that continue to captivate scientists in this field.



Talk link: https://youtu.be/rwB_iWb9F9Y



Biosignatures: On Earth and Beyond

Speaker: Priya Shah Hasan, Maulana Azad National Urdu University, Hyderabad, India

This article is a review of biosignatures that are used to study habitability and/or the presence of past or present life in our solar system and exoplanets. We discuss the evolution of biosignatures through the period of life on Earth. For the Earth, undisputed biosignatures are only detectable for about a quarter of the Earth's past. In other periods, detectable biosignatures are not totally reliable and can only determine a statistical likelihood estimate of life on Earth. We also discuss results obtained from various habitability experiments in our solar system. We conclude with a focus on the importance of the study of biosignatures in the new era of exoplanet research with the launch of the James Webb Space Telescope and the era of extremely large ground-based telescopes.



Talk link: <https://youtu.be/8u3WkqcNrQg>

Any characteristic, atom, molecule, substance, or attribute that can be used as proof of past or current life is referred to as a “biosignature”. Biosignatures have not yet been found on any exoplanet. The reliability of probes of biosignatures on planets in our solar system and beyond is important to study in the era of extraordinarily big ground-based observatories that are more than thirty meters and the James Webb Space Telescope (JWST), which is stationed in space.

This talk is a review of biosignatures that are used to study habitability and/or the presence of past or present life on the Earth that can be applied to exoplanets. We discuss the evolution of biosignatures through the period of life on Earth. For the Earth, undisputed biosignatures are only detectable for about a quarter of the Earth's past. In other periods, detectable biosignatures are not totally reliable and can only determine a statistical likelihood estimate of life on Earth.

The Earth's observable spectrum has changed over its 4.5 Gyr lifespan. As previously stated, this was brought on by alterations in the surface through time, variations in temperature, and chemical. Let's consider how spectroscopic data could reveal the existence of life on Earth from space and throughout time.

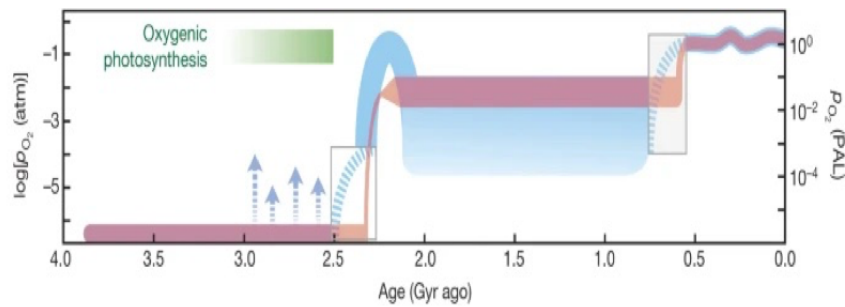


Figure 1: The changing oxygen concentration of Earth's atmosphere over time (Kaltenegger et al., 2007).

Kaltenegger et al. (2007) created a model to comprehend the impacts of geological evolution on the Earth's atmosphere and surface and to produce spectra of observations of an Earth-like planet over the course of its life.

Although H_2O and CO_2 are vital components of life and are unmistakable indications of it, they are not appropriate for use as biosignatures because they were present in the Earth's atmosphere long before life began to exist there. They can be utilized as certain signs of life if the abundance of these molecules is greater than what could have been present before life emerged. Thus, the abundance of CH_4 from 3.5–4 Gyr ago and the existence of H_2O , CO_2 , and O_2 in the visible and thermal infrared regions of the spectrum are unequivocal signs of life (Kaltenegger et al., 2007).

The presence of large amounts of CH_4 does not necessarily mean that there is life there, as it might be a byproduct of atmospheric chemistry or be brought about by potential non-biological processes such as the oxidation of a planet's crust and upper mantle.

Only in the most recent 10% of the solar system's age were the biosignatures O_2 and O_3 detectable in the visible and thermal infrared spectrums. While N_2O could only be discovered in later stages in the early Earth, methane could only be detected with limited resolution.

O_2 and N_2O are unmistakable signs of life. O_2 must be produced synchronously and replenished in order to be detected because it is very chemically reactive.

O_2 and O_3 characteristics in the visible and thermal infrared regions of the spectrum are signs of photosynthetic biological activity that occurred throughout the solar system's past existence. It would only have been able to detect signs of the solar system in spectra within the last 10% of the solar system's age. The thermal infrared at 7.75 m has three weak N_2O signatures.

Methane was detectable in the early Earth, 3.5 Gyr–0.8 Gyr ago, with N_2O being detectable only in the later universe, 0.3 Gyr ago.

The chloro-fluorocarbons CCl_2F_2 and CCl_3F found in the atmosphere of the modern Earth in the infrared wavebands are further potential biosignatures. For low-resolution spectroscopy, their abundances are too low, though.

In order to identify biosignatures and determine whether a planet is habitable, it is crucial to

know the distance to the planet, its evolutionary stage, and its spectral resolution.

The existence of clouds is another crucial element that must be taken into account. Clouds reflect regardless of wavelength, but they also obscure molecules below them, making spectral lines in the thermal infrared and visible spectrum appear fainter (Helling 2019).

It is straightforward to guess what the Earth's spectrum would look like today by looking at the Earthshine spectrum. The type of flora on exoplanets that has been observed, which results in various spectrum fingerprints, is another significant unknown. Models of the spectra of many planets with various types of photosynthesis were created by Tinetti et al. in 2006.

In conclusion, observations of CH₄, CO₂, N₂O, H₂O, O₂, and O₃ in the visible to near-infrared parts of the spectrum are required if we are to find planets with life similar to that found on Earth.

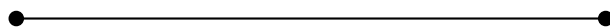
Comets include fossilized records of the early solar system. The comet 67P Churyumov-Gerasimenko's nucleus was discovered to contain 40% organic materials (by mass) by the ESA's Rosetta mission, which terminated in Fossil records of the early solar system can be found in comets. ESA's Rosetta mission, which ended in September 2016, found that the nucleus of comet 67P Churyumov-Gerasimenko contained 40% of organic matter (by mass).

There isn't, in theory, a single indisputable evidence or "smoking-gun" biosignature. Work is being done on models for various types of geology, life, and conditions on planets that may enable us identify a variety of species or molecular types in the atmosphere to confirm that what we see is not the result of naturally occurring geological processes but is rather the consequence of life. Finding life and figuring out what exoplanets' surfaces look like will depend greatly on this.

In the present era of exoplanet research with the launch of the James Webb Space Telescope and the era of extremely large ground-based telescopes this is of utmost importance.

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Exoplanets and the Definition of Habitability

Speaker: Chris Impey, University of Arizona, USA

With 5500 exoplanets known, hundreds are Earth-like and potentially habitable, projecting to ten billion across the Milky Way galaxy. Earth's habitability can be re-interpreted in the light of the extraordinary diversity of exoplanets. All planet atmospheres evolve, and habitability does not mean that biology can or will arise. Life on Earth has nearly been extinguished several times and many exoplanets are likely to be more hospitable to biology. This includes terrestrial planets with many times Earth's inventory of water, super-Earths, and nomad or orphan planets drifting through interstellar space with no star. Upcoming observations are discussed that will begin to characterize the habitability of exoplanets in detail.



Talk link: <https://youtu.be/sxauUBOCXPw>

Habitability of the Earth

Habitability is a moving target. Earth has suffered from extreme conditions and catastrophic changes in the distant past. We sit precariously at the inner cusp of the Sun's habitable zone, teetering on the edge of over-heating. Long before the Sun runs out of nuclear fuel, it will start burning hotter. Eventually, the effect of the extra solar radiation will dwarf the climate change we're currently worried about. It will get hot enough to evaporate the oceans and obliterate surface life. Cloned plants have identical genetic material. However, they can become distinct if they grow up in different environments. Similarly for planets. Small differences get magnified over time. Imagine two identical Earths where a small difference in the star's radiation alters the evolutionary clock by 10%. After 4.5 billion years on one you would find plants, animals, and us. While after 4.5 billion years the slightly cooler Earth might only have barren land and no life in the oceans larger than the head of a pin.

Around 4 billion years ago, the atmosphere held much more carbon dioxide, methane, and ammonia than it does now. Earth was a water world, with oceans high enough to submerge today's continents above the level of Mount Everest. There was no oxygen so this early Earth would have been fatal to us. Life had probably already started in the oceans, although it would be almost impossible to detect from afar. By 3.5 billion years ago, carbon dioxide had declined, and the atmosphere was predominantly composed of nitrogen. Three subsequent epochs trace the rise of oxygen from 0.2% to its current value of 21%. Our Earth and the air we breathe have changed drastically since the Earth formed 4.5 billion years ago. Far from being inevitable, the habitability of the Earth has always been "touch and go". The climate has veered from

ocean-boiling heat to planet-wide deep freeze. Simulations suggest the long-term habitability of our planet wasn't inevitable but was contingent. It could have gone either way and we are literally lucky to be alive. Living Earths might be much rarer than we hope.

Biology and Habitability

Water is essential for life, and life is found everywhere there is significant water. The questions then become: what is the minimum amount of water needed for biology to function, and how does that compare to the amount of water on Earth and available in exoplanet environments? The answer to the first question is very little. If we travel to the driest locations on the Earth, such as parts of the Atacama Desert where there has been no measurable rain in a century, we will find microbial life on or near the surface. Similarly for the Antarctic dry valleys, which are the closest to a Martian environment on Earth. Organisms that can tolerate extreme physical conditions are called extremophiles; those that can handle extreme dryness are called xerophiles. Some of these organisms have evolved novel biochemistry to compensate for the lack of water. Others go into suspended animation, with minimal water and metabolic activity dormant. In one case in the Antarctic, a cell mat that had been dormant for two decades began photosynthesis after one day of exposure to liquid water. Some microbes have even survived the absolute aridity and vacuum of deep space aboard the Space Shuttle. All branches of the tree of life can manage this trick of going dormant—bacteria, yeast, fungi, plants, and animals.

Extremophiles expand the envelope of habitability. The traditional astronomy definition refers to planets where the surface temperature is in the range where water can be a liquid. Life on Earth tells us this is too restrictive. Extremophiles are found below the freezing point of water, and above its boiling point, near deep-sea hydrothermal vents, and far below the surface in mines and even in solid rock. Our knowledge about exoplanets is still too primitive to sense or diagnose any of these environments.

Habitable Exoplanets

Let's look at all exoplanets where water can exist. Our scope includes mini-Neptunes, two to four times the Earth's size. Then homing in on home, we arrive at rocky planets somewhat larger than the Earth. Super-Earths are up to twice the size of our planet and up to eight times its mass. These two categories make up two thirds of the 5600 known exoplanets, yet they are unknown in the Solar System. The main difference is that the larger mass and size of mini-Neptunes is due to an outer layer of hydrogen and helium that contributes most of the mass.

Are water worlds habitable? Since water is essential for life, it might seem so, but there can be too much of a good thing. If the rocky core was sealed into a water sarcophagus, there might not be enough nutrients for life. Also, the geochemical cycle that's essential for Earth's habitability would be shut down. Scientists are divided, however, because it might be dangerous to project our Earth-centric perspective onto these alien worlds. You need to build up from basic physics and chemistry, rather than relying on Earth's analogy in order to tackle exoplanets.

Avoiding the most massive, water-dominated planets, an argument can be made that super-Earths are likely to be super-habitable. Most of them will orbit red dwarf stars, with much longer lives for sustaining life than our Sun. The extra bulk of a super-Earth also helps its habitability. The core stays hot for longer, and tectonic activity replenishes the carbon dioxide, without which

the greenhouse effect would fade, and oceans would freeze. An active core also sustains a protective magnetic field. The atmosphere would be thick, and higher surface gravity would increase erosion and make a flatter surface. This sounds boring but it has an advantage for life. Super-Earths are likely to have many shallow islands, and as on Earth, biodiversity would be rich in such an “archipelago world.” Living there might be tolerable but dragging around in the stronger gravity would be tiresome. And leaving would be difficult. The SpaceX Falcon Heavy rocket can launch 25 tons into Earth orbit, but on a super-Earth, with twice the escape velocity, it could barely put a child into orbit.

The Search for Earth Clones

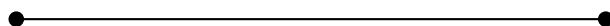
We have not yet found a clone of the Earth. By which we mean a planet with Earth’s mass and Earth’s size on a year-long orbit of a yellow, middle-aged main sequence star. NASA maintains a dashboard of exoplanet discoveries. They can be plotted in terms of their masses and their orbital periods. About 75% have been found with the transit method and 25% with the radial velocity method. Radial velocity planets range from ten Earth masses to ten Jupiter masses, with orbital periods from a month to ten years. Sensitivity is too low to find small terrestrial planets. Transit planets range from below Earth’s mass to Jupiter mass, with orbital periods ranging from a few days to a few months. Most planets are larger than the Earth and on more rapid orbits of their stars. The time span of data isn’t long enough to find small planets on one-year orbits.

However, if we relax the requirement that the planet orbits a star like the Sun, there are several near twins of the Earth. Most stars are less massive than the Sun. Red dwarfs are from 10% to 50% of the mass of the Sun, the lower number representing the limit where a star becomes too cool to shine by fusion. They have lived for hundreds of billions of years, and there are a hundred red dwarfs for every star like the Sun. Twenty of the thirty stars nearest to the Sun are red dwarfs, including the closest, Proxima Centauri. Red dwarfs have slender habitable zones that are much closer than the habitable zones of Sun-like stars are. However, the vast number of red dwarfs means that their habitable “real estate” is great that the habitable real estate around stars like the Sun. Other factors weigh against them as places where life might develop. Red dwarfs emit X-rays which would irradiate any planet nearby. Red dwarf planets are tidally locked to always have the same face pointing to the star, creating large temperature gradients from daytime side to nighttime side. Their habitability is hotly debated, but researchers believe conditions will not preclude life.

Astronomers have defined an “Earth Similarity Index”, which is designed to characterize how similar a planet or a moon is to the Earth. It has a scale of zero to one, where the Earth has a value of one. The index incorporates the planet’s size, density, surface temperature, and escape velocity. It does not calculate planet habitability or the ability of a planet to host life, just the similarity of its bulk properties to our planet. Using this scale, Mars has an index of 0.64. Mars is smaller than the Earth yet may have subsurface life, so it is a planet on the “edge” of habitability. A database of potentially habitable planets lists 48 with an index higher than Mars. Nine of these planets have indexes of 0.85 or higher, including two in the TRAPPIST system and Proxima Centauri b.

If we haven’t found an Earth clone yet, it might still exist. The exoplanets detected so far are almost all within 4000 light years. That’s just 1% of the Milky Way, which is 100,000 light years across. With tens of billions of terrestrial planets in the galaxy, probability and common sense

says that many will be very similar to the Earth. Multiply by 100 billion galaxies in the observable universe, and the projection becomes ten billion billion (10¹⁹) terrestrial planets around Sun-like stars and fifty times more around red dwarfs. The nearest exact twin may be on the far side of the galaxy or in another galaxy millions of light years away.



Exoplanet Atmospheres

Speaker: Nathan Mayne, University of Exeter, UK

In this presentation, I will describe how we detect and characterise planets beyond the solar system (or exoplanets), focusing on how we use models and theories developed for the study of Earth's weather and climate to explore these distant worlds. I will discuss how studies of the first life on Earth, and the evolution of the life-climate system on Earth, alongside studies of Venus and Mars are contributing to our understanding of the potential prevalence of life in our galaxy and its potential detection. I will describe detailed observations of large, hot exoplanets, or Hot Jupiters, what these observations tell us about their climate and how these techniques might help us to detect life beyond Earth!



Talk link: https://youtu.be/Z8hX_eJq-no



Planets are everywhere! Since the detection of the first planet beyond the solar system we have learned that they are both ubiquitous and diverse ranging from extremely hot gas giant planets (hot Jupiters) to planets potentially able to host life (e.g., Trappist-1e). However, how do we detect and study these distant worlds? In this talk I will detail how we explore the atmospheres of distant planets. Through combining simulations (for example, 3D climate models as visualised in Fig 1.) to comparison with cutting-edge observations (as shown in Figure 2), we can learn about planet formation and evolution in general but also take lessons home to Earth, to improve our understanding of our own changing climate.

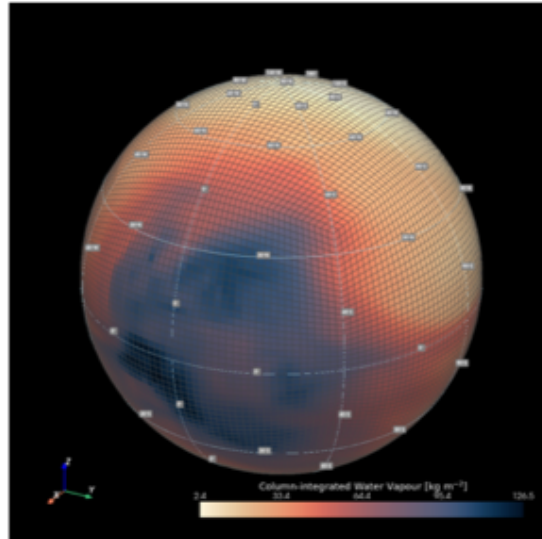


Figure 1: Simulated atmosphere of Trappist-1e, showing water vapour content (Sergeev et al., 2023).

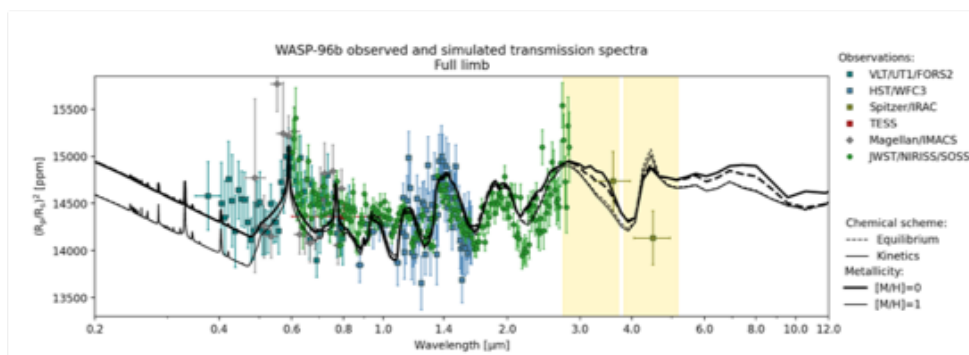
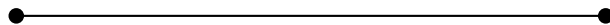


Figure 2: JWST observations of 'hot Jupiter' Wasp 96b (dots and crosses) alongside 3D model predictions (solid lines) from Zamyatina et al. (under review).



Introduction to the Climate App and Its Educational Resources

Speaker: Julie Bolduc-Duval, Discover the Universe, Dunlap Institute, University of Toronto, Canada

Collaborators: Nicolas Cowan, McGill University, Canada

How does the greenhouse effect work? How do we know the temperatures on the planets around other stars? All these questions can be studied thanks to the ClimateApp, an interactive web tool that creates a simple model of the atmosphere. We will show you how to use this tool in the classroom and we will go through the educational resources we've developed around it. Lots of potential for discoveries with your students! Note: the ClimateApp and the educational resources are available in English and French.



Talk link: <https://youtu.be/TuDjbwV8rLw>

The Climate App was created by Nicolas Cowan and his team at McGill University. It can be accessed online at climateapp.ca and is also available in French at appliclimat.ca. The Discover the Universe team, led by Julie Bolduc-Duval, created educational content to help secondary school teachers use the Climate App with their students (recommended age: 13+).

What is the Climate App?

The Climate App is an interactive web-based application that describes the radiative transfer governing planetary climate. It is suitable for teaching high-school through college students, or public outreach. The beginner version can be used to explore the greenhouse effect and planetary albedo, sufficient for explaining anthropogenic climate change, the Faint Young Sun Paradox, the habitability of TRAPPIST planets and other simple scenarios. There is also an advanced option with more atmospheric layers and incorporating the absorption and scattering of shortwave radiation for students and educators wishing a deeper dive into atmospheric radiative transfer.

The graphical panel of the Climate App is a visual representation of the energy flows controlling the planet's climate. The pale blue swath above the planet's surface represents the atmosphere. The yellow arrows show shortwave radiation from the star, roughly corresponding to visible light for the Sun. The red arrows represent longwave thermal emission, typically infrared, from the planetary surface and atmosphere. The width of each arrow is proportional to the importance of that energy flow as compared to the amount of starlight that reaches the planet. This sort

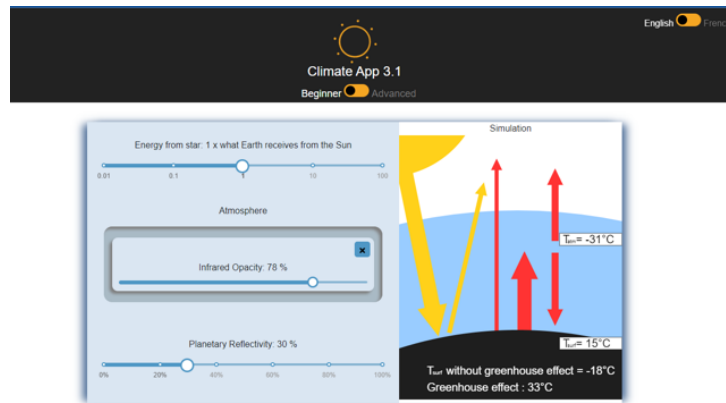


Figure 1: Screenshot of the Climate App - climateapp.ca.

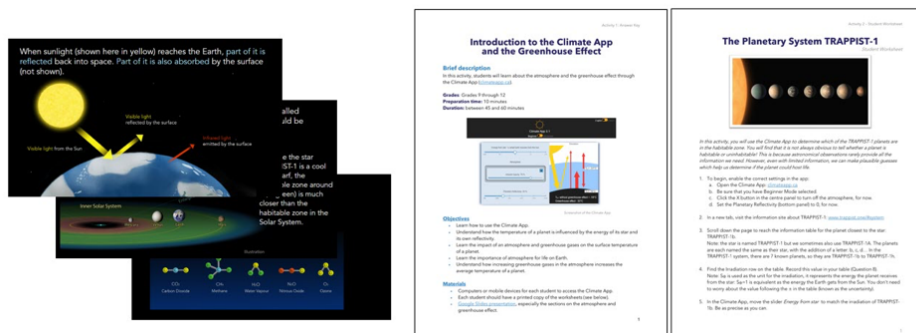


Figure 2: Educational resources connected to the Climate App.

of schematic showing energy flows in a planet's atmosphere is sometimes called a Trenberth Diagram and is commonplace in climate studies of Earth and other worlds.

Moving the sliders in the control panel changes the planetary parameters and hence the way that energy flows in and out of the atmosphere, which is ultimately what governs the surface temperature. Temperatures are reported in Celsius for the beginner version and Kelvin for the advanced version. The beginner version of the app also reports the magnitude of the greenhouse effect in degrees Celsius; this is the difference between the surface temperature and the value it would take if the infrared opacity of the atmosphere were zero. The default values of the sliders when you open the Climate App, both the beginner and advanced versions, are approximately the average values for modern-day Earth.

The control panel on the left lets you vary the planet's properties and hence its climate with the corresponding sliders. Three properties are common to both versions (energy received from the star, the infrared opacity of the atmosphere, and the planetary reflectivity or albedo) while two extra properties are present exclusively in the Advanced version.

How to use in the classroom

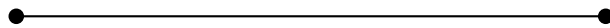
The educational activities can be found on the Discover the Universe website at <https://www.discovertheuniverse.ca/resources> and in French at <https://www.decouvertedelunivers.ca/ressources>.

A set of slides is available as Google Slides (English - French) and provides background information

on many concepts needed to use the Climate App. It is not intended to be used as a lecture set of slides, but instead we invite teachers to use the section they need to make sure the students are comfortable with the subjects. It covers how sunlight affects the Earth, the electromagnetic spectrum, atmospheres, the greenhouse effect as well as exoplanets and their systems.

The first educational activity is an introduction to the Climate App and allows students to learn about the atmosphere and the greenhouse effect. It invites students to play with each slider on the App to determine how that parameter affects the surface temperature. At the end, students should understand that the infrared opacity of the atmosphere increases when fossil fuels are burned and the impact it has on the surface temperature. The second educational activity uses the Climate App to determine the surface temperatures on the exoplanets of the TRAPPIST-1 system. By using the irradiance for each planet (found on an external website) and making assumptions about the planets' conditions (albedo, atmosphere), it is possible to get a surface temperature. Students are then invited to comment on these assumptions and realise what information we are still missing about these exoplanets.

The educational project around the Climate App isn't over. In the next few years, we are hoping to develop more content, including short videos explaining the science behind the App and featuring the scientists involved. We are also looking at creating new educational activities for the secondary school level. The Climate App has a lot of potential for education. If you have ideas, please contact us!



Environmental School “Awareness of the Habitable Planet”

Speaker: Irma Fuentes-Morales & Mariana Duran, Universidad de Santiago de Chile (USACH) and Ruta Sustentable Environmental Foundation, Chile

Collaborators: Diana Pozo, Department of Meteorology, Universidad de Valparaíso, Chile; Omar Cuevas, Department of Meteorology, Universidad de Valparaíso, Chile; Julio Marín, Department of Meteorology, Universidad de Valparaíso, Chile; Yara Jaffé, Physics department, Universidad Técnica Federico Santa María, Valparaíso, Chile; M. José Ochoa-Muñoz, CIDEMAR Foundation, Valparaíso, Chile; Daniel Muñoz, Ruta Sustentable, Valparaíso, Chile; Catalina Schiappacasse, Ruta Sustentable, Valparaíso, Chile; Nynozka Andrades, Ruta Sustentable, Valparaíso, Chile

The Environmental School “Awareness of the Habitable Planet” (the word ‘conciencia’ in Spanish also reads as “with science”) is an itinerant initiative that promotes environmental education for boys and girls in the secondary school cycle. Multidisciplinary workshops help address the habitability conditions of the planet, in direct contact with scientists from the areas of atmospheric, marine, astronomy and environmental sciences. The environmental school complements the school curriculum using an “Exploration Log” to assess content learning. With nature visits, an environment of awareness is created, fostering a sense of hope in practical solutions. The school promotes the STEM approach and collaborative work, providing children with tools to be agents of change in society from early age.



Talk link: <https://youtu.be/nBtKpFsth8c>

Constantly we receive hopeless messages about the climate crisis and the accelerated degradation of the environment. Recently, as a result of the very high temperatures reached in the summer in July 2023, the secretary general of the United Nations, António Guterres, declared that on the subject of climate change: “The only surprise is the speed of change. Climate change is here. It’s frightening. And it’s just the beginning. The era of global warming is over. The era of global boiling has arrived” [1].

At the global level, the countries that contribute the most to global warming are China with 29% and United States with 11%, and at the local level, although Chile is a country that contributes very little to the emission of greenhouse gasses only (0.25%), it will be one of the countries that will be most affected by the consequences of this climate crisis [2].

We are currently undergoing major changes. We are the first generation experiencing the tangible impacts of climate change, and the last generation that can act to mitigate and adapt



Figure 1: Illustration of the logo of the environmental school awareness of the habitable planet. Designed by Mariana Durán.

to this phenomenon. There is no doubt that climate change must be the most important issue of our time. For these reasons, it is urgent to communicate the reality that we are living and will live in the near future as inhabitants of planet Earth [3].

Why communicate about climate change from the perspective of astronomy?

The members of the astronomical community have a unique understanding of the conditions necessary for a planet to support life. To date, more than 5000 exoplanets have been discovered in our galaxy. However, none of them are suitable for human habitation. Even options like Mars or Jupiter's moons are not viable in the near future. Therefore, it is crucial to recognize that our planet is irreplaceable and there is no alternative, no "Planet B" where we can relocate. On the other hand, Venus and Mars can be presented as examples of scientific understanding of the greenhouse effect on planetary atmospheres. Thus, we can conclude that Climate change is an astronomical issue. Therefore, education plays a key role in emphasizing the uniqueness of our planet and the need to protect and preserve it.

In this way, and in order to highlight these slogans, a few years ago, the astronomical community created the network Astronomers for Planet Earth, whose mission is to share and collect information to educate about these issues in a hopeful way, since with so much bad news to communicate, it is very important that the message should be imparted from a perspective of hope, not fear.

Environmental school format

Based on this background, In 2019, the situation just described inspired us to create a multi-disciplinary itinerant environmental school, named "Environmental School Awareness of the Habitable Planet" (see Figure 1). This school format allows us to create an environment of collective awareness without falling into demotivation. We contribute to the sense of hope through the development of activities in direct contact with nature, influencing their vision and their present and future interactions with the environment. The objective of the school is to explore the conditions necessary for the habitability of our planet by integrating various scientific disciplines, connecting these topics with the elementary school curriculum, and providing students with a holistic understanding of the subject matter.



Figure 2: a) Simulating the creation of clouds in the workshop “How does the atmosphere of our habitable planet work?”. b) Star party developed in the workshop “Distances in the Solar System and habitability” of the environmental school during 2022.

The school was specifically designed for children between the ages of 8 and 12 and it was implemented during 2021 and 2022 for about 100 children. It comprises six scientific workshops that cover a variety of subjects such as atmospheric and marine sciences, astronomy, and environmental education. The didactic material was collaboratively developed by scientists specializing in these fields, as well as primary school teachers. This collaborative effort aimed to ensure that the activities within the material align with the learning objectives outlined in the current school curriculum. These subjects are taught using active learning strategies, collaborative work, and direct interaction with nature, encouraging active participation and hands-on exploration.

To assess the content, we designed a book called “The Explorer’s Log”, which served as a workbook and collectible sticker book. The purpose of the “Explorer’s Log” book was to provide a structured and interactive way for participants to engage with the material. The activities of each workshop were evaluated using the logbook. The central spread of the logbook presented a grid with coordinates, which were printed on the stickers that the children received after completing each activity. The illustration created for this sticker collage included every location where the itinerant school took place.

Multidisciplinary Workshops

1. How does the atmosphere of our habitable planet work?

This workshop was carried out by meteorologists, who created activities that show the role played by our planet’s atmosphere, at the same time describing how global warming affects atmospheric phenomena. The workshop is divided into activities which are carried out using reusable waste such as plastic and glass bottles. One of them consists of showing how the clouds are formed, from the condensation of water in a bottle by introducing a lit match, with the objective of explaining the process of how precipitation will be in a warmer future climate (see Figure 2a). The workshop ends with the creation of tornadoes in an experiment that requires two plastic bottles joined at the neck, water and vigorous shaking. In this way they get to experience, on a small scale, events that are becoming more and more recurrent due to climate change.

2. Distances in the Solar System and habitability

This workshop was developed by astronomers, aims at collecting the children’s impressions regarding the probabilities of inhabiting other planets in the solar system, in relation to the distances of these planets from the Sun. Fun riddles and cards with the planets’ characteristics

were used to simulate and scale down the distances of the planets in the Solar System (see Figure 2b). The activity ended with a star party that included night-sky observations with telescopes, and for many of the participants it was the first experience they had observing the sky in this way.

3. Climate action plan

The last workshop aims to propose solutions that can be addressed by every person on the planet to mitigate the impact of human activities on ecosystems. During the workshop, the children had the opportunity to observe the ecosystem using magnifying glasses and binoculars and to plant a tree to learn the importance of vegetation in absorbing CO₂.

Conclusions

Through active learning strategies and direct contact with nature, the environmental school promotes collaborative work and STEM topics, in addition to promoting children's rights, recognizing that from childhood people can be agents of change in society, helping to strengthen their inclusion and the development of their empathy for the preservation of nature.

References:

- [1] United Nations. (27 July 2023). Hottest July ever signals 'era of global boiling has arrived' says UN chief. <https://news.un.org/en/story/2023/07/1139162>
- [2] Olivier, J. G. J., Bouwman, A. F., Van der Maas, C. W. M., & Berdowski, J. J. M. (1994). Emission database for global atmospheric research (EDGAR). *Environmental Monitoring and Assessment*, 31, 93-106.
- [3] Williamson, K., Rector, T. A., & Lowenthal, J. (2019). Embedding Climate Change Engagement in Astronomy Education and Research. *Bulletin of the American Astronomical Society*, 51(7), 49.

POSTER CONTRIBUTIONS

Planetary Climates and Critical Thinking in STEAM Education

Presenter: Harufumi Tamazawa, Japan

When the discussion of planetary climate is used in education, it is often stressed that the importance of conservation of the global environment and the survival of humankind is important. Considering that the timescale of astronomy is longer than the timescale of human existence, academic discussions and educational ideas do not necessarily match. There are also efforts to incorporate the perspective of environmental ethics into STEAM education. When seriously trying to incorporate ethical and philosophical perspectives into STEAM education, there are times when we think about the pros and cons of human survival. Although this material is effective in training critical thinking, it should be considered carefully, especially in the context of primary and secondary education.



Poster link: <https://doi.org/10.5281/zenodo.10445015>

In 2023, NASA published a workshop report on the ethical and social implications associated with the Artemis program. Legal discussions have been held for a long time, and ELSI in cutting-edge science and technology. As part of the discussion, space exploration, especially the development of the Moon and Mars, has become a target. Suggestions regarding educational content include: "A brainstorming group suggested that ethics training be integrated into STEM education materials as well as internships and early-career in-house training." It is desired that the contents of ELSI be incorporated into STEM or STEAM education.

In 2022, UTSA in the United States and Kyoto University in Japan have launched programs for university students to learn space ethics (ethics related space science and astronomy). Along with its connection to security, the pros and cons of altering planetary climates are also one of the research topics in space ethics.

While it has been recognized that an approach to education regarding ethical aspects is needed in both space development and education settings, concerns about how to deal with it in education have yet to be considered.

This approach is often seen in which 'A' in STEAM education is considered a liberal arts, and the consideration of ethics and philosophy is put into practice. The modification of the planetary climate mentioned above is also a topic that can be covered in STEAM education. However, it is not easy to judge whether this content can be covered in elementary and secondary education. For example, the major premise of reorganization of the planet's climate can be the survival of humanity. However, in matters such as space ethics, where the scope of research includes re-examining ethics itself in the special environment of space, the survival of humanity is not a prerequisite but one of the questions that should be questioned. While such issues are excellent material for critical thinking, it is necessary to carefully consider whether it is appropriate to begin considering content that could shake one's values before receiving specialized training. STEAM education with the motif of planetary development is being practiced in various elementary and secondary schools, but it is necessary to carefully approach the validity of discussing the pros and cons of human survival in K-12 education.

References:

- [1] NASA (2023). Artemis, Ethics and Society: Synthesis from a Workshop <https://www.nasa.gov/wp-content/uploads/2023/09/otps-artemis-ethics-and-society-report-final-9-21-02023-tagged.pdf>

DISCUSSION SUMMARY

This session provided an overview of the latest scientific research on planetary climate, from Earth to the other planets and moons in the Solar System, to exoplanets. Given the wide scope of the topic, the session was split into two main parts with a total of 10 talks and one poster. The discussions centred around the urgent issue of climate change, approached from different perspectives depending on the session, and explored strategies for educators to improve their communication on this topic with students.

During the panel discussion of the Earth's climate and future perspectives session, we heard about the consequences of climate change for different sectors and how to address the topic with students. Natalya Gomez discussed how even a low rise of the sea levels will have noticeable repercussions, and she urged us to take action with the phrase 'Be brave, not perfect'. When engaging students on this matter, both Natalya and Nicolas Cowan recommended emphasising actionable steps rather than dwelling on the negative aspects. This approach aims to convey an empowering sense rather than overwhelming the students. On a different note, Faustine Cantalloube detailed how climate change has impacted astronomy research, noting that the social repercussions will be a significant factor affecting astronomers. To address the climate crisis from an astronomical perspective, concerned scientists and educators have formed the Astronomers for Planet Earth movement. The speakers invited educators and researchers to join the group's Slack channel to access their educational resources and keep up with their activities. Philip Nelson presented a new approach to demonstrate the effects of greenhouse gases at an undergraduate level, sparking audience discussions on presenting this topic at a school level.

In the session addressing climate beyond Earth, the panel discussion covered the topics of exoplanet atmospheres and life on other worlds. Chris Impey explained why we look for life outside the Earth as we know it highlighting the associated challenges. Nathan Mayne stressed the importance of considering the building blocks of life when looking for it elsewhere, and how life can affect a planet's fate, as it might have happened in the Solar System. Speakers agreed on the importance of having tools to teach students about climate and raise awareness of Earth's uniqueness. Irma Fuentes-Morales and Mariana Duran shared their positive experiences with their Environmental School "Awareness of the Habitable Planet" in Chile and were open to others adapting the activity in different contexts. On behalf of Julie Bolduc-Duval, Nicolas Cowan answered questions about The Climate App and shared their plans to translate it to other local languages.

The main takeaway from the panel discussions is that, although thousands of exoplanets have been discovered, Earth stands as the only one harbouring life. This perspective underscores the essential requirement for us to responsibly steward and prioritise the well-being of our planet.

Astronomy Education Beyond the Classroom

Session organisers: Eduardo Penteado (OAE Heidelberg), Niall Deacon (OAE Heidelberg), Exodus CL Sit (NAEC Hong Kong), Sandra Benitez (ESA and GalileoMobile, Spain), Ángela Perez (Planetarium of Medellin, NAEC Colombia)

SESSION OVERVIEW

This year's Shaw-IAU Workshop on Astronomy for Education featured one practical astronomy education session that delved into the realm of teaching astronomy beyond traditional classroom settings. The dedicated session, titled "Astronomy Education Beyond the Classroom," provided an in-depth exploration of innovative approaches and initiatives in astronomy education, focusing on diverse environments like science centers, planetaria, and astronomy clubs.

The session was strategically structured into three sub-sessions: Planetaria, Science Centers, and Museums—highlighting interactions with formal education beyond mere edutainment; Scientists returning to schools, exploring the impactful dynamics of experts engaging with students; and Amateur Astronomy in a School Setting & Beyond, showcasing the integration of amateur astronomy into formal education contexts and beyond. With a robust lineup featuring 23 talks and 15 posters, the session uncovered a rich variety of methodologies, collaborative efforts, and pioneering initiatives that transcend the conventional boundaries of classroom-based learning.



The Power of Astronomy Museums

Speaker: Patrícia F. Spinelli, Museum of Astronomy and Related Sciences, Brazil

Astronomy Museums serve not only as repositories for the wonders of the universe, but also as catalysts for exploration, inspiration, and transformative learning. These spaces represent a convergence of the past with the future, where science intersects with culture, and the power of education assumes a cosmic dimension. Indeed, many of the important dimensions that museums hold are common dimensions in Astronomy Education. That is to say, our Astronomy Education initiatives can learn from Museum education and take advantage of the non-science aspects to engage with the various public.



Talk link: <https://youtu.be/R7ASSwNU5MA>

According to the International Council of Museums

A museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets, and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing.

Its origins can be traced back to the Cabinets of Curiosity during the Renaissance and Baroque periods (16th to 18th centuries). Aristocrats of that era engaged in the practice of collecting objects that could showcase their wealth, taste, and knowledge. These collections found their place in dedicated chambers or rooms. Among the accumulated objects, were natural specimens, fossils, minerals, dissected animals from exotic places, and more.

According to Podgorny (2008), the deliberate arrangement of objects, aimed at creating a pathway to understand a larger narrative of the objects and highlight differences between them, is a unique phenomenon in European history. This practice gradually paved the way for the creation of museums and early natural museums.

It can be asserted that the earliest science museums, the first generation, began taking shape during the 18th and 19th centuries as natural history museums, showcasing collections of this

nature to the public. For instance, the Wagner Free Institute in Philadelphia, established in the 1850s, continues to house Victorian cabinets of meticulously mounted specimens, organized by classification. Therefore, the collection and the systematic arrangement of objects are defining features of what a science museum is.

The second generation of science museums dates back to the early 20th century. They placed a greater emphasis on the use of technology for educational purposes. What distinguishes these museums from the first generation ones is a fundamental shift in the purpose of objects on display — a shift from passive contemplation of objects to active engagement with them facilitated greater understanding. A noteworthy example of such a museum is the Deutsches Museum, founded in 1903, in Munich.

A vivid example of the third generation science museums, also called science centers, is the Exploratorium, in San Francisco, which has set a new standard for science centers globally, inspiring many others to adopt a similar approach and advance science education through interactive experiences. Thus, it becomes clear that education takes on a different dimension in the realm of science museums. Unlike many other types of museums, science museums and centers prioritize education to a remarkable extent.

Education in Museums

According to Hopper-Greenhill (2017, p.4) and many other scholars on the subject, “the context for learning in museums is not the same as in schools or in other sites for formal education.” Rather, “museum-going is about free-choice learning, and free-choice learning in museums is about identity formation and maintenance” (Falk, 2009, p. 61).

With this in mind, we can formulate the foundations of Museum Education, that according to the Brazilian Museum Education Policy (Brazil, 2019, p.), “is an educational process, centered on the individual and their interaction with society, which values their ways of creating and living culture, politics, and history.”

Museum Education exhibits three unique characteristics. (1) The temporal dimension, which has two facets. Firstly, it concerns the amount of time visitors typically spend in museums, which is often around 2 hours. Secondly, it encompasses historical time, as museums allow visitors to explore the past, present, and sometimes even the future. (2) The dimension of space, in which the overall visitor experience is enhanced through the grand architecture of museum buildings. In addition, the exhibit design contributes to aesthetic encounters, while visitors also have the freedom to select what they wish to explore, aligning with their individual interests. (3) The third dimension is the object, which is central to a museum’s identity and mission. Objects act as tangible links to the past and convey the stories and knowledge that museums communicate. These aspects collectively contribute to making museum education a dynamic and influential force in promoting lifelong learning, inspiring curiosity, and fostering a deeper understanding of the world and its many facets. Nonetheless, as a researcher and museum educator, I would like to introduce another very important aspect to museum education – the audience. Museum visitors, driven by free choice, form a diverse group varying in age, objectives, and familiarity with the subject matter.

Public Observatories and Astronomy Museums Across the World

In 2017, we conducted a survey to gather insights from astronomy museums and public observatories worldwide regarding the utilization of historically valuable telescopes for public observations (Spinelli & Ribeiro, 2018). We extended invitations to members of the International Astronomical Union to participate in the survey, which entailed responding to a questionnaire made available over a three-month period.

Seventy institutions confirmed that they were carrying out public observation of the sky with instruments considered of historical value, with a notable concentration in the Global North. The majority of these institutions function as departments or sectors within universities. Only 11% of them indicated that they were also officially recognized as museums. This recognition designates them as heritage sites within their respective countries, denoting their historical, cultural, or architectural significance. Such designation often comes with legal protections to preserve their heritage value.

Some examples of the institutions found in our study are: the Royal Observatory in Greenwich, in the United Kingdom; the Cincinnati Observatory in the USA; the Sydney Observatory in Australia; the Museum of Astronomy and Related Sciences itself, in Brazil; and the Astronomical Observatory of Federal University of Rio Grande do Sul.

In our survey, astronomers or other professionals working at some of the institutions participating in our survey shared their perspectives on the power and impact that experiences of using heritage telescopes for observation have on the audience. In their opinion, observing through the historic telescopes offers a distinct and tangible experience, evoking 'wow' moments for visitors. Visitors appreciate the psychological impact of sharing the same view as famous figures from the past.

The impressions of MAST visitors with the 21cm centenary reflector were gathered in a study presented by Bassallo (2016) and Spinelli et al. (2018). A conclusion drawn from various testimonies showed that the atmosphere and the environment of the antique dome are highly valued. The use of a real artifact of science connects people to astronomy and the combination of its age and exclusivity creates a sense of wonder.

Astronomy Education and Museum Education Ground

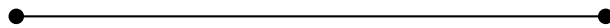
Practitioners in Astronomy Education/Communication understand that its impact extends far beyond the realm of science and technology. Recognized as one of the oldest sciences, astronomy's roots lie in the observation of celestial objects, regulating timekeeping, and predicting seasons across diverse cultures. It serves as the backdrop for creation stories that impart moral and cultural precepts to younger generations in many cultures with oral tradition. Therefore, astronomy encompasses historical and cultural dimensions. Prompting contemplation about our place in the universe also introduces a philosophical dimension. On the opposite end of the spectrum, the allure of astronomy is not solely intellectual; many people are drawn to it for the sheer beauty experienced during stargazing. Thus, it is clear that Astronomy Education has many common aspects with Museum Education.

Final Remarks

Astronomy Museums serve not only as repositories for the wonders of the universe, but also as catalysts for exploration, inspiration, and transformative learning. These spaces represent a convergence of the past with the future, where science intersects with culture, and the power of education assumes a cosmic dimension. Indeed, many of the important dimensions that museums hold are common dimensions in Astronomy Education. That is to say, our Astronomy Education initiatives can learn from Museum education and take advantage of the non-science aspects to engage with the various public.

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Connect Your Class with Science Using Skype a Scientist

Speaker: Sarah McAnulty, Skype a Scientist, USA

Skype a Scientist is an informal science education nonprofit that matches scientists with classrooms, scout troops, and libraries for Q&A sessions about science for free! In this program tutorial, Dr. Sarah McAnulty will explain how teachers can get the most out of this program.

Talk link: https://youtu.be/LiA-ztedh_c



Rejuvenating Astronomy Education and Research at Yerkes Observatory

Speaker: Mallory Conlon, Yerkes Observatory, USA

Often called the birthplace of modern astrophysics, Yerkes Observatory maintained its status as one of the world's premier astronomical observatories throughout the 20th century. Now, through leadership from Yerkes Future Foundation and support from the community, Yerkes is entering a period of rejuvenation. In an effort to reconnect communities across Wisconsin with Yerkes and the field of astronomy in a meaningful way, we are rebuilding Yerkes' education and research programming. In this talk, we will highlight what we have done since taking over ownership in 2020 and provide insight into Yerkes' plans for the future.



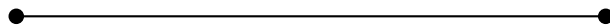
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In an effort to connect with our visitors in a meaningful way, Yerkes Observatory staff are working to create a series of education and outreach initiatives designed to broaden participation and engagement with astronomy. As an institution, we are committed to building a future where Yerkes inspires creativity through exploration, art, and a connection with the cosmos; a future where imagination, collaboration, and scientific curiosity thrive and transform the world. Each initiative will work toward this broad goal and will focus on one of the three primary audiences: general audiences; K-12 students and teachers; and early career researchers, including undergraduates and graduate students.

To that end, we are working to rebuild Yerkes' education and research programming, ultimately restoring the observatory's place as a center for discovery. As we work to build these programs, one resounding theme we are focusing on is providing access to our visitors — access to not only Yerkes and its history, but also the field of astronomy and astrophysics, and access across a wide range of populations. Yerkes' programs will aim to connect people of all ages and backgrounds with astronomy's history, present, and future, and inspire within them a curiosity for the Universe. We also want to promote a welcoming and inclusive environment for our audiences to learn and feel empowered to pursue their interests regardless of their past experiences. Yerkes' strength lies within its ability to seamlessly juxtapose astronomy's past, present, and future; by bringing astronomy enthusiasts and young people to Yerkes and engaging them in educational activities and observing, they become part of Yerkes' story. Visitors at Yerkes walk the same halls as astronomy greats such as Hubble and Chandrasekhar, leading them to ponder what their impact on the field could be. To that end, our team is focusing on developing educational

and research experiences that highlight how science is not just a body of facts but a creative endeavor, while also providing access to this inspiring place to those that are marginalized in astronomy, particularly people of color, women, and first generation college students. We aim to provide the resources and technology needed to explore astronomy and STEM as a passion or as a career.

Our programming is new, with the majority of programs launched in Summer and Fall 2023. As we continue to build and expand our programming, we are working toward developing a robust, mixed-methods evaluation plan, including surveys and conversations with visitors following their experiences. Doing so will help ensure that our programs are meeting our intended goals and our audiences are engaging with astronomy in a meaningful way. We look forward to sharing results from these evaluations of our programs in the future.



Astronomy Learning Community: Fostering Research in High School Students

Speaker: Elizabeth Villanueva, Global Hands-On Universe, Chile

Collaborators: Carlton Pennypacker, Bonie Thurber, Fraser Lewis, and Global Hands-On Universe

Introducing GWAM Astronomy Learning Community, uniting Chilean teachers and students. The goal is astronomy advancement via modeling and photometry. Weekly sessions explore key concepts, using modeling as a research tool. The community fosters knowledge exchange, teamwork, and skill development. Results show enhanced engagement, interest, and understanding. GWAM empowers high school students for autonomous astronomical research, bolstering Chilean education and nurturing future astronomers.



Talk link: <https://youtu.be/W5Q1AWqwbrw>



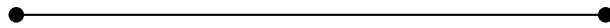
This talk introduces an innovative initiative, the GWAM Astronomy Learning Community, which brings together teachers and students from different schools across Chile. The primary goal of this community is to promote astronomy learning through the methodology of modeling, using photometry programs for the analysis of astronomical images.

The program takes place on a weekly basis, providing participants with the opportunity to explore and understand key concepts in astronomy. Students are introduced to modeling as a fundamental tool for scientific research, enabling them to acquire practical skills to conduct their own astronomical investigations in the future.

The learning community facilitates the exchange of knowledge and experiences among participants, encouraging collaboration and teamwork. Students not only acquire theoretical knowledge but also develop research skills, problem-solving skills, and critical thinking.

Preliminary results from the implementation of this program demonstrate increased interest and engagement among students in the study of astronomy. Additionally, an improvement of their understanding of scientific concepts and the ability to apply them to real problem-solving was observed.

GWAM aims to train high school students to independently conduct astronomical research. This innovative approach seeks to strengthen scientific education in Chile and promote the education of future researchers in the field of astronomy.



A Trip to the Planetarium – the Full Experience

Speaker: Mathias Jaeger, Planetarium Mannheim, Germany

A visit at a planetarium can be much more than watching an immersive video on the dome. It can be a live changing learning experience which leaves the students in awe! The Planetarium Mannheim hosts 15 000 students a year. With a newly developed format the students receive live presented and age adapted interactive shows, Q&A sessions with an astronomer, as well as online material for preparation or follow-up learning experiences in the class room. This talk presents how this new type of full planetarium experience was set up, its advantages and disadvantages, as well as the challenges which had to be faced.



Talk link: <https://youtu.be/vQDbntKJip4>

A 100 years ago the first artificial stars were projected in a planetarium in Jena. But the stars were just the beginning! In the last century the planetariums changed drastically, opened up to other sciences, cultural events, music festivals, and much more. But one thing remained: the fascination of the visitors to the crystal clear night sky projected to the dome of the planetarium. A night sky many never experienced on their own as the nights became more and more polluted with artificial lights.

As such the planetarium is the ideal medium to transfer astronomical knowledge to the general public; a medium and a means of conveying our science that many other natural sciences are jealous about. More than 4000 planetariums exist worldwide, attracting millions of visitors every year. Many among them are school children of all ages whose teachers want to use the planetarium and the expertise of the people working in them as an engaging way to increase the fascination of their students to astronomy. However, a visit to the planetarium can be much more than watching the stars or an immersive video. It can be a life-changing learning experience which leaves the students in awe!

The Planetarium Mannheim hosts more than 15 000 students – age 6 to 19 – every year. With a newly developed format the students receive – if wanted - live presented and age adapted interactive shows, Q&A sessions with a trained astronomer, as well as online materials for preparation or follow-up learning experiences in the class room: in other words, a full planetarium experience.

An experience which is not always easy to deliver!

Since the dome of the Planetarium Mannheim seats 220 people, we have up to eight different classes during a presentation. This makes it incredible challenging to perform interactive live

presentations where we aim to ask questions to the students, perform age appropriate jokes, and present astronomical knowledge appropriate to their age. The visiting students come from various backgrounds, have different background knowledge, and also different levels of motivation to actually learn about astronomy. As such, in some cases, it can happen that the presenter cannot always act as the friendly entertainer but must enforce the rules of the planetarium. In doing so, the presenter risks ruining the "out of school" experience for all visitors.

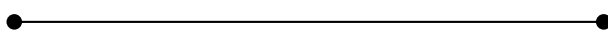
To mitigate these effects, we find it of great importance to welcome the students and their teachers already outside the dome, providing an opportunity to interact with them before the actual presentation. It gives the presenter a feeling for the students and the students get a chance to meet the presenter beforehand.

The whole visit to the planetarium, in particular the Q&A session after the actual presentation, is a rare opportunity for the students to interact with a scientist – a trained astronomer in our case. During the Q&A session, students and their teachers have the chance to ask questions that weren't addressed during the presentation and to clarify anything they didn't understand. The last part is especially important for the presenters, because they receive feedback that enables them to further improve their presentation and explanations.

The drawback of these Q&A sessions is that they can get quite long for students not interested in astronomy. On top of that, hardly ever can all questions be answered due to time restrictions. For this reason, we began offering students the option to submit their questions electronically after their visit, and we respond to these questions via email.

Due to the different skills needed for such school visits – the presenter needs to understand the planetarium technique, needs educational and entertainment skill, and have a broad astronomical knowledge to answer as many questions in the Q&A session as possible – there is only a limited number of personnel available which can perform these sessions. Training new personnel is extremely time consuming and not all employees are both willing and capable of doing this type of presentation.

The planetarium experience doesn't end here though. Students being very interested in astronomy need further engagement possibilities after their school visits. Therefore, we created a youth group – age 12 to 16 – which gets dedicated lessons on astronomy as well as a course on telescope handling. With this knowledge, students can borrow telescopes from the planetarium and use them either at home or together with their class spreading the fascination for astronomy even further. On top of that, we often set up special events for our youth group and other students in the area. These events include visits and talks by astronauts, Nobel Prize winners, famous scientists, and presentations at special astronomical and space related events. This whole package creates the full planetarium experience!



Quest-Based Activities for Astronomy Learning at an Observatory Visitor Centre

Speaker: Robert Cumming, Onsala Space Observatory, Chalmers University of Technology, Sweden

Collaborators: Josef Wideström, Chalmers University of Technology, Sweden

The inaugural exhibition at the new visitor centre at Onsala Space Observatory in Sweden was developed involving school classes in a co-creative process. To increase engagement for visiting classes and lowering thresholds for informal learning in astronomy, we have evaluated quest-based activity cards. We have explored different types of quests requiring different types of interaction with the exhibition. We find that while different age groups have widely diverging needs, the cards provide a good low-cost way of upgrading the experience at the exhibition for a large variety of visitors.



Talk link: <https://youtu.be/WCj7M9dPv6U>

Onsala Space Observatory is Sweden's national research infrastructure for radio astronomy. Its new visitor centre, opened in September 2022, is located next to three large radio telescopes (13-25 m) and close to many other instruments for astronomy and Earth sciences. At the centre, we have helped develop a new exhibition aimed at a wide audience, with target ages 10-15, supported by grants from the Hasselblad Foundation. As the "big idea" [2] for the exhibition, we have worked with the slogan: "Radio and space technology help us to think big enough to understand our planet, the cosmos, and our place in the universe."

Like science centres, visitor centres serve as vital platforms for visitor interaction with scientific phenomena, fostering hands-on learning experiences where interaction and learning are intertwined. Research shows that interactive exhibits enhance visitors' educational experiences by enabling active exploration and problem-solving, leading to a deeper understanding of scientific concepts [1]. The design and implementation of exhibits can significantly affect learning outcomes [3]. The challenge is to reduce barriers to interaction and exploration and create meaningful experiences for diverse target groups. For school classes, field trips are most effective as sources of first-hand, original experiences and exploration [6], in the best case giving unique learning outcomes distinct from classroom-based instruction. Recent research underscores the profound impact of informal learning through exploration on visitors' attitudes toward science

and scientific literacy, especially benefiting individuals with limited prior scientific knowledge [4] [5].

Testing a self-guided exhibition

At Onsala, we have studied groups of visitors on two-hour guided tours and at public events. The visitor centre exhibition, designed in-house with co-creative input from local schools, was aimed at self-guided exploration. From the outset, and with an incomplete exhibition, we tested the experience with visitor groups. We discovered early on that younger kids were quick to lose interest in self-exploration. As a solution, we introduced quest-based activity cards, after a suggestion from Petra Hellgren at Curiosum in Umeå.

Our initial set of activity cards were 20-25 sheets of A4, printed out for each new group. Each showed a different suggested activity. We challenged visitors in pairs to choose any card, do the activity, then return for a different task. Getting distracted by something else in the exhibition is encouraged, and we didn't check for completion or correct answers. We grouped the challenges in four types: activity, self-measurement, discussion, and quiz question.

We tested these with around 20 different visitor groups (years 2, 5, 6, and 9, as well as high school students at public events). We found that the cards engaged visitors in exploring the exhibition independently for at least 15-20 minutes. The instruction texts were too hard for age 11 and under, leading to many requests for help from adults. Easy-to-understand activities were chosen most often (e.g. space-themed Memory game, comparing weights on different planets).

In a second iteration, we adapted the cards and grouped activities according to topic. We wanted to connect aspects of the exhibition to the school curriculum. We also simplified both text and graphics. To investigate the different types of challenge, we included four on each card. Six cards dealt with the following topics: astronomy, radio astronomy, tech, chemistry & biology, and art/images. On each card there were four types of tasks: self-measurement, activity, quiz question, or discussion.

The modified cards were tested in three classes (year 5, year 6, and high school) and at one public event. These cards too engaged visitors for 15-20 minutes, we found. The cards also stimulated direct feedback: one pupil responded to their first card's first question, "What's the weather like?" with the comment "Well that sounds boring!". In general, the written descriptions and graphics were still a barrier for 11-12-year-olds, however, we identified an important aspect of the activity that could be improved: how the cards were introduced. Visitor groups need to be focused and attentive to be ready for the cards, and achieving this may require different interventions.

What we've learnt

Our activity cards facilitate self-guiding and learning in the exhibition. They also provide us with a visitor-exhibition interface that we can develop in the future, helping us gather feedback and input for reflection [7] on what visitors find more or less stimulating. Comparing ages 10-12 with 13-15 and upwards, we find that challenges work better for older learners than younger ones.

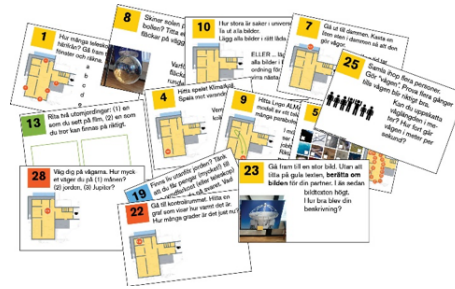


Figure 1: Eight-year-olds exploring the exhibition and (right) the initial activity cards.

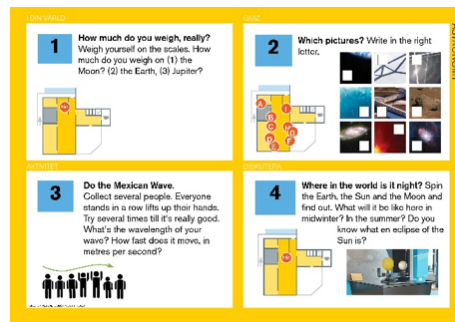
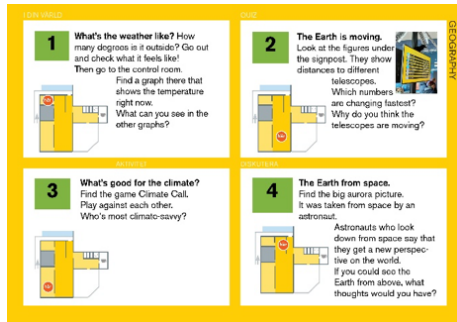


Figure 2: Activity cards: two of the six cards in the second iteration. For use with different groups, the cards have Swedish text on one side and English on the other.

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Behavioural Impact of Visitors at the Astronomy Gallery in Regional Science Centre and Planetarium Calicut

Speaker: Jayant Ganguly, Regional Science Centre and Planetarium Calicut, India

Astronomy Galleries are public spaces where one expects to learn or relearn the general ideas from the varied topics of astronomy. Any science gallery unfolds the concepts of a topic as the visitors moves from one exhibit to another. The galleries are developed keeping in mind that after one completes a tour of the gallery, he or she develops a holistic understanding of the theme through their multisensory interaction with the exhibits in the gallery. People crave the perception and assimilation of findings and discoveries when presented in a planned, immersive, and cohesive way. This talk reflects upon the decade long observed behavioral impact of visitors at the Astronomy gallery in RSCP Calicut.



Talk link: https://youtu.be/2iCEk_QeqXI

Astronomy Galleries are public spaces where one expects to learn or relearn the general ideas from the varied topics of astronomy. Any science gallery unfolds the concepts of a topic as the visitor moves from one exhibit to another. The galleries are designed with the intention that, after completing a tour of the gallery, visitors develops a holistic understanding of the theme through their multisensory interaction with the exhibits in the gallery.

Astronomy Gallery exists in many science museums and planetariums that unfold aspects of the universe. People crave the perception and assimilation of findings and discoveries when presented in a planned, immersive, and cohesive way. This talk reflects upon the decade long observed behavioral impact of visitors to the Astronomy gallery at Regional Science Centre and Planetarium Calicut (RSCPC) in Kerala, India.

RSCPC is a part of National council of Science Museums (NCSM), a national scientific organization dedicated towards science popularization across all sections of the society through science galleries, planetariums, and science parks.

Inaugurated on 7th March 2010, the 'Hall of Astronomy' is categorized into four subsections:

1. Pre-Telescopic Era
2. Post-Telescopic Era
3. Sun & Solar system
4. In Search of Cosmic Truth



Figure 1: Entrance to the 'Hall of Astronomy'.



Figure 2: Visitor movement in the 'Hall of Astronomy'.

The pre-telescopic era takes us through the antiquity when astronomers were mostly thinkers, philosophers, and mathematicians. They tried to understand the heavens through the logic of daily experiences. They imagined various models of the universe and the solar system. Aristotle argued in favour of an Earth-centric universe (popularly called **geocentric universe**). Ptolemy explained the complex motions of the planets through epicycles, having a dogmatic assumption that all the heavenly motions could only occur through a perfect curve or a combination of such curves, which constituted a circle. Copernicus was a revolutionary to propose the **heliocentric** concept. From thinkers, the trend gradually shifted towards accurate observations and analysis. The champion among them was Tycho Brahe. The work done by his young assistant, who carried out a thorough analysis of the master's observed data for 16 years, resulted in the three laws of planetary motion by Johan Kepler.

The post-telescopic sections start with homage paid to the architect of modern science, Galileo Galilei, who took the revolutionary step of pointing the telescope to the sky and observed the details of heavenly objects. This stopped the process of guessing and imagining, paving the way for experimentation in the study and understanding of science. That one act gradually changed our perception of the universe. Furthermore, in this section of the exhibition there are models showing how a reflector, a refractor, works. A working exhibit of radio telescope gives us insight into the working of these instruments.

Next is the section of 'Sun and solar system', where topics related to celestial events observed from Earth and facts relating to the Sun and the solar system are highlighted. Exhibits in this section showcase the effects of Precession and Nutation. Following these, there are exhibits



Figure 3: Weigh yourself in different planets.

on eclipses, transits, and occultations, dramatically displayed through a participatory exhibit where visitors can play and learn the causes of these phenomena. An animated model of the Sun illustrates its internal structure, while an electro-mechanical model of the solar system (also called an **orrery**) demonstrates how the planets move around the sun. Additionally, an exhibit allows visitors to see how much they would weigh on different planets. Near the gallery entrance, there is a working Foucault pendulum, whose plane of oscillation changes with time, visually demonstrating Earth's rotation. The Celestial sphere, an important tool for astronomers, is also one of the highlights of this section.

Coming to the last section, there is a working exhibit featuring a pulsar, along with an exhibit on astronomical spectroscopy. Additionally, there is an 'Astro Quiz' corner where visitors can test their knowledge in astronomy. There is also a kiosk describing the various career options in the field nationally. The gallery boasts a rich collection of colorful infographics, containing information on various aspects of astronomy.

In this presentation, I spoke about some of our observations of the visitors to this gallery over the last decade. We tried to address a few questions, such as the following:

1. On which exhibit people spend more time interacting with them?
2. Which label people spend more time reading?
3. Whether people discuss among themselves while interacting, trying to understand the exhibit?
4. Whether people follow the exhibit sequence when going through the gallery?
5. Whether people have doubts regarding any particular (groups of) exhibits?

The decade-long observed behavioral impact of visitors at the Astronomy Gallery at the Regional Science Centre and Planetarium Calicut (RSCPC) provides valuable insights into how individuals engage with astronomy-related exhibits. The gallery is divided into four subsections, each covering different aspects of astronomy, thus offering a range of exhibits and interactive displays. Here are some key observations and insights from the study:

1. **Visitor engagement:** The study found that visitors spend varying amounts of time interacting with different exhibits. Some exhibits seem to capture more attention than others, suggesting that certain topics or displays are more engaging or appealing to visitors. Understanding which exhibits are more popular can help in designing and curating future exhibitions.

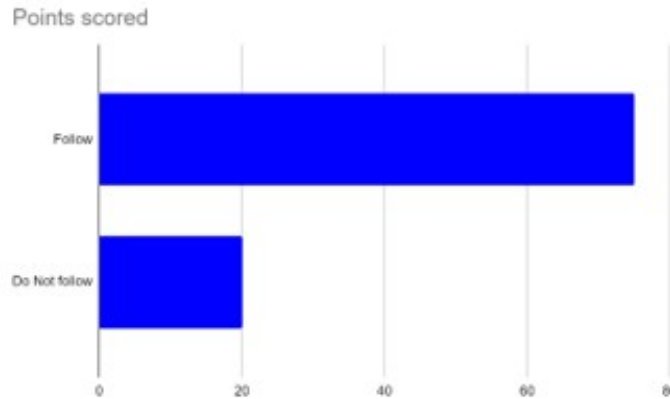
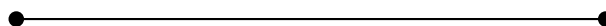


Figure 4: Comparative graphics depicting visitor movement in the gallery.

2. **Label reading:** Visitors also differ in their reading habits. Some spend more time reading the information provided on labels or graphics accompanying exhibits. This indicates an interest in gaining in-depth knowledge about specific topics. It's essential to make sure that the information provided on labels is accurate, engaging, and informative.
3. **Social Interaction:** The study found that visitors often engage in discussions with each other while interacting with exhibits. This social interaction suggests that astronomy galleries can be a place for learning and sharing knowledge collectively. Encouraging group discussions and social learning can enhance the overall visitor experience.
4. **Exhibit sequence:** The object of observation was also the sequence of exhibits that visitors go through while navigating through the gallery. Understanding how visitors move through the exhibits can help optimize the layout and flow of the gallery to ensure that the information is presented in a logical and coherent manner.
5. **Visitor queries:** Some visitors may have specific questions or doubts about certain exhibits or concepts. Providing avenues for visitors to seek clarification, such as volunteer assistance or Q&A sessions, can enhance their understanding and overall experience.

In conclusion, the study highlights the importance of designing astronomy galleries and science exhibitions with a focus on visitor engagement, learning preferences, and social interaction. By understanding how visitors behave and interact with exhibits, science museums and planetariums can improve the design and curation of future exhibitions to create more immersive and educational experiences for their visitors, thereby becoming centers of learning beyond the classroom environment.



What Do People Really Talk About Inside the Dome? A Detailed Look at Planetarium Communication Topics

Speaker: Joana B. V. Marques, Instituto de Astrofísica e Ciências do Espaço, University of Coimbra, Coimbra, Portugal

Collaborators: Ilídio André Costa, Santa Bárbara School Cluster / Porto Planetarium – Ciência Viva Center / Instituto de Astrofísica e Ciências do Espaço – University of Porto, Portugal; Miguel Gomes, Natural History and Science Museum, University of Porto, Portugal

Planetariums are key settings for science education and communication. They enable the exploration of a wide range of astronomy topics and ideas. Usually, sessions are adapted and tailored to the public, and content plans are prepared and put in practice. But, in the end, what exactly is communicated during these sessions? What do guides and their audiences really talk about? To answer these questions, we recorded video and audio during planetarium sessions with minimum disturbance, in different Portuguese institutions. The content communicated in these live sessions was then analysed. In this talk, we present preliminary results of the review of that content and explore its connections with the Portuguese curriculum guidelines and the IAU guidelines for astronomy literacy.



Talk link: https://youtu.be/uCTj0_jiQ8U

Introduction

In this study, we present preliminary results of a broader research designed to understand the content communicated in planetarium sessions in Portugal. Despite the growth of Astronomy Education Research in recent decades [1] and the planetarium being the most studied setting [2], there is still little focus on the characteristics of planetarium sessions as they happen. Studies analyzing what was explored and discussed in these sessions are rare [3]. With this study, using a naturalistic approach, we aim to map and characterize the content that is, in fact, communicated in planetariums in Portugal, understand the common points and differences among different sessions, and investigate the existing connections with the Portuguese school syllabus (the “Essential Learnings”) [4] and the Big Ideas in Astronomy (a proposed definition of astronomy literacy, endorsed by the IAU – International Astronomical Union) [5].

Data and Analysis

Data was collected in planetariums from different Portuguese institutions. Sessions were recorded in video and audio with minimum disturbance for the participants, using a naturalistic approach. A total of 34 live sessions were recorded so far. In this preliminary study, we

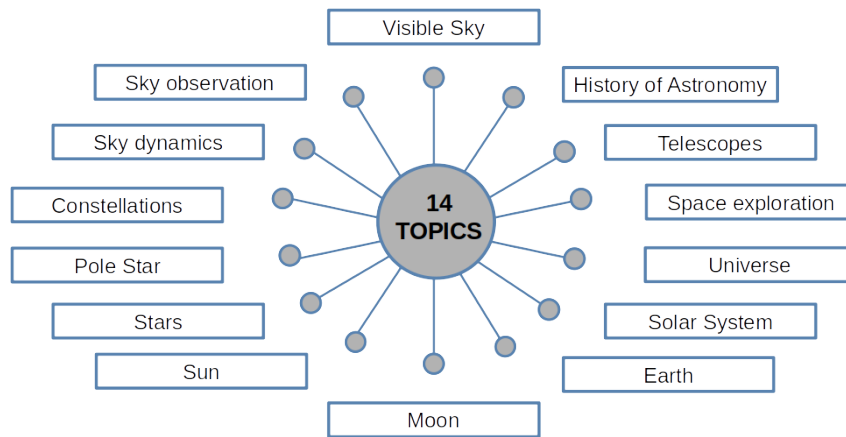


Figure 1: Categorization of the Astronomy topics communicated in the planetarium sessions.

analyzed a corpus of six of those sessions, from different institutions and diverse public. The recordings were fully transcribed, and the analysis involved categorizing the content by topics and relating them to the Essential Learnings and the Big Ideas in Astronomy.

Results - Astronomy Topics

Analysis of the six planetarium sessions revealed a very dynamic and rich panorama. In general, both daytime and nighttime are simulated, and the observable sky is, as expected, used to communicate topics related to Astronomy. The guides/educators in these sessions also incorporate complementary media such as images and film projections, and props like globes. The categorization of these sessions' contents resulted in a total of 14 topics (see Figure 1), subdivided into 149 more specific ideas.

The topics with more expression are “Visible sky”, “Sky dynamics”, “Solar System” and “Earth”. There is a predominant focus on positioning astronomy and topics related to objects in the Solar System. Much of the communication is related to the discussion of the dynamic characteristics of the Earth and the Solar System, and its consequences in the visible sky. Moreover, concepts related to the preservation and awareness of contemporary problems, such as light pollution or the importance of observing and connecting with the sky, are also present. These preliminary results also show that general topics seem to be transversal to different audiences and guides.

Results - Essential Learnings

The Essential Learnings (EL), divided by school subjects and grades, are the mandatory syllabus established for the Portuguese formal education system. As in most countries in the OECD (The Organization for Economic Cooperation and Development), Portuguese formal education includes Astronomy [6]. But this is very superficial, except for the 7th grade of basic education. In this grade, the syllabus includes two Astronomy-dedicated topics. Nevertheless, throughout all mandatory schooling, there are only a total of 23 ELs directly related to Astronomy.

Results from which ELs were present in our data (see Figure 2) show a total of 37 different ELs. Of these, 15 are directly related to Astronomy (dark blue in Figure 2). There is, then, a group of school astronomy content (8 out of 23 Astronomy ELs) that is not present in the sessions studied. On the other hand, there are 22 ELs related to other subjects, such as History or Geography, showing interdisciplinarity in these planetarium sessions. Moreover, around 10% of all the content communicated is not related to Essential Learnings, indicating that the planetarium

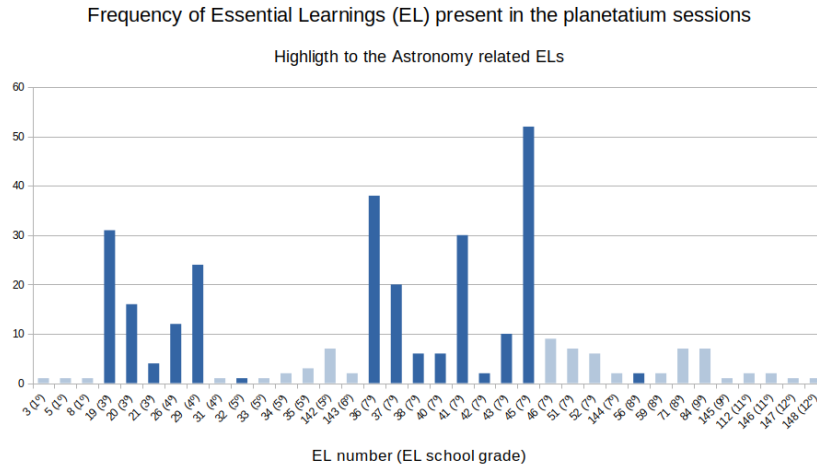


Figure 2: Presence of different Essential Learnings (Portuguese school syllabus) in the planetarium sessions studied. Dark blue ELs are directly related to Astronomy.

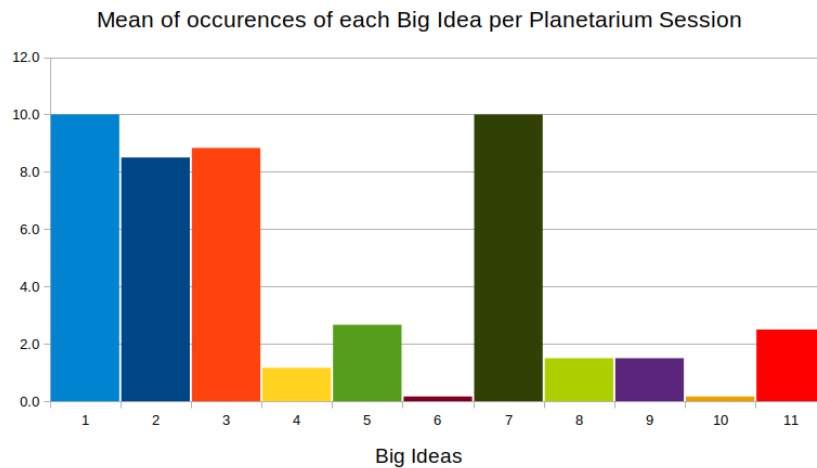


Figure 3: Presence of different Big Ideas in Astronomy in the planetarium sessions studied.

goes beyond the school syllabus.

Results – Big Ideas In Astronomy

Finally, as we explore which Big Ideas in Astronomy are present in the planetarium sessions, we notice a clear tendency for the communication of the following ideas 1 - “Astronomy is one of the oldest sciences in human history,” 2 - “Astronomical phenomena can be experienced in our daily lives,” 3 - “The night sky is rich and dynamic” and 7 - “We all live on a small planet within the Solar System” (Figure 3). This is consistent with topics related to the observable sky and the Solar System, but when we explore the sub-ideas the panorama is more complex. Moreover, there are gaps, groups of sub-ideas, that are never mentioned in any of the sessions studied. Naturally, these results need further analysis and a larger corpus to be fully understood. Nonetheless, with these preliminary results, we can start asking: Are there Big Ideas that are not suitable for the planetarium? Can we propose sessions that go beyond the obvious topics?

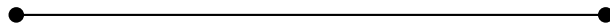
Final Considerations

The planetarium sessions studied are very rich in astronomical content but are not limited to it.

They also delve into other subjects in an interdisciplinary way, extending beyond the astronomy syllabus in formal education. These preliminary results show tendencies that an expanded and refined analysis can later clarify by pursuing the following questions: is there a core group of topics, and of Astronomy Essential Learnings and Big Ideas, transversal to most sessions? Which ones? On the other side, what is missing (both in Essential Learnings and Big Ideas)? Can/should these gaps be addressed, and such missing content and ideas introduced? How can we use the planetarium better for different purposes? And in general, can this practical communication of astronomical knowledge in the planetarium help us identify and strengthen relations between Astronomy Literacy and the Formal Curriculum? By mapping and understanding what is in fact communicated in live, real planetarium sessions, we hope to contribute to answering these questions.

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Making a Successful STEM Project Inclusive

Speaker: Joanna Holt, NOVA (Netherlands Research School for Astronomy) & AUAS (Amsterdam University of Applied Sciences), The Netherlands

Collaborators: Joris Hanse, The Netherlands Research School for Astronomy (NOVA); Marieke Baan, The Netherlands Research School for Astronomy (NOVA) & NOC for The Netherlands; Steven Bloemen, Radboud University, Nijmegen, The Netherlands; Jacco Vink, Anton Pannekoek Institute, University of Amsterdam; Ralph Wijers, Anton Pannekoek Institute, University of Amsterdam; Frans Snik, Leiden Observatory, University of Leiden; Sebastiaan de Vet, Delft University & KNVWS; Jotte Hof, The Weekend School; Frans Stravers, Netherlands Institute for Space Research (SRON), The Netherlands; Judith Mulder, The Weekend School

The NOVA Mobile Planetarium strives to give all children in the Netherlands an unforgettable STEM experience during their school career. Since 2009, the project has inspired almost 500,000 school students across the Netherlands. The NOVA approach has real impact on its visitors as the shows are fully live and interactive. Recent collaborations with planetarium projects around the world are broadening the reach of the NOVA vision further. By any standard metric, it is a success story! However, self-reflection during the relative quiet of the Covid-19 pandemic revealed the project does not reach all areas and demographics in the Netherlands – the project is not yet fully inclusive. In this talk, we outline the roadmap designed to turn the NOVA Mobile Planetarium into a truly inclusive project.



Talk link: <https://youtu.be/GUDcUrsj0qo>

The NOVA Mobile Planetarium

The Netherlands Research School for Astronomy (NOVA) is the collaboration of the four Dutch astronomy Universities in Amsterdam, Groningen, Leiden and Nijmegen. In addition to research and astronomical instrument and telescope development, NOVA also has a small, dedicated education, media, and public engagement team. The flagship education project is a network of three Mobile Planetariums [1]. Two domes are coordinated by NOVA and cover nine of the twelve Dutch mainland provinces. The third dome is coordinated by colleagues at the University of Groningen and visits the remaining three provinces. The NOVA Mobile Planetarium project began in 2009 and has since reached more than 500,000 school children of all ages. The goal of the project is to give every child in the Netherlands an unforgettable STEM experience during his/her school career.

Each dome is approximately 6.5m wide and 3.25m high and can accommodate around 30 people, the typical size of a school class in the Netherlands. The planetariums use the best professional

software available, to which NOVA has added a customised dashboard, developed in-house. All planetarium shows are fully live and interactive – there are no scripts and presenters are trained to tailor the shows to the interests and level of the group. This is possible because the presenters are astronomy students, studying at one of the NOVA universities – astronomy students have a good general astronomy knowledge. NOVA also views the young, diverse group of student presenters as important role models for the school students attending planetarium shows; particularly for pre-university students, the age gap between presenter and school student can be as little as a couple of years. See [1] for more details.

During the Covid-19 pandemic, NOVA rapidly modified its approach offering planetarium experiences with a flat screen or online [2,3,4]. This flexible approach has led to a large increase in bookings which are, in 2023, at almost three times pre-pandemic levels [1].

In addition, NOVA works in partnership with a large, fixed planetarium in The Hague in the Netherlands (Museum-Omniversum, capacity 300). NOVA also supports other planetarium projects overseas such as the Statia Mobile Planetarium project in St. Eustatius in the Dutch Caribbean, the planetarium project linked to the Africa Millimetre Telescope (AMT) project in Namibia [1,5,6,7], and the 100-planetarium project led by former ESO-Alma Director Thijs de Graauw in Chile.

Impact and visit distribution

Since 2009, the two NOVA-coordinated domes have reached more than 500,000 school students across the Netherlands. Currently, the project visits around 3 times the number of schools that visited prior to the pandemic. The type of visits has also changed. Pre-pandemic 80% of visits were to secondary schools and 15% to primary schools. Today, 55% of visits are to primary schools and 35% to secondary schools [1].

At face value, the statistics look great. However, mapping all visits since 2009 shows that the geographical distribution of visits is not perfect. The planetarium often visits the same areas, and the project structurally misses poorer neighbourhoods in the cities and many rural areas — a problem faced by many public engagement efforts.

Plan of action

NOVA's vision is to give an unforgettable STEM experience to every school child in the Netherlands during his/her school career. To achieve this, we have developed an ambitious plan to increase inclusivity.

Firstly, the project needs to increase capacity. In early 2023, we purchased a new planetarium thanks to generous sponsorship from the Dutch Space Research Institute, SRON.

Second, we are carrying out a research project to understand the problem. This research is generously funded by a Dutch astronomer with a large personal grant. We know from interactions with some teachers that the reasons we do not visit all schools is complex. Some schools are not aware of the project, others think the project is regional, and some schools cannot afford the contribution NOVA asks for to cover the cost of the visit (transport and student contribution). However, we do not understand how representative these views are or if there also are other reasons that we do not reach all schools. The research is currently in progress (autumn 2023) and includes short questionnaires for primary and secondary schools. We are

specifically targeting the geographical areas we miss, and the questionnaires will be followed up by individual interviews and focus group sessions.

Once the situation is clear, we will finalise our plan of action. We currently expect this to include a combination of:

- i. Reaching out to missed schools and, where necessary, offering subsidised visits.
- ii. Collaborating with the 'Weekend School', an organisation providing extra-curricular activities for highly motivated learners from disadvantaged areas. In addition to providing planetarium lessons, we will also work together with the Weekend School to develop new training for our planetarium presenters. This training will be based on the expertise of the Weekend School in the best teaching methods to create a learning dialogue with this demographic.
- iii. Taking the planetarium 'on tour', specifically to provide (subsidised) visits to schools in more rural areas.
- iv. Increase the visibility of the planetarium project in general, by attending and giving workshops at education conferences.

We also plan to structurally evaluate all of our actions in order to ensure the actions are sustainable.

Finally, this plan is ambitious and requires funding. In addition to the sponsorships mentioned above, we have now also secured a Science Communications grant from the Dutch Research Council (NWO), awarded in November 2023.

Conclusion

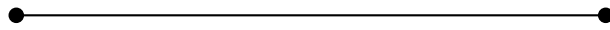
The NOVA Mobile Planetarium project visits schools across the Netherlands. Since 2009, the project has reached more than 500,000 students. However, a critical review of geographical distribution of the visits revealed that not all demographics are reached. NOVA has embarked on an ambitious plan to make the project truly inclusive, reaching every school child in the Netherlands, and has secured funding to achieve this.

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M is for Mars and Metaverse: Bringing New Experiences to Students Through Virtual Reality Education

Speaker: Elizabeth Tasker, JAXA, Japan

Collaborators: Jim Green (Metavisionaries), Trudi Hoogenboom (Astra Nova School), Wasim Ahmed (Metavisionaries)

It is extremely fun to describe a star forming region while taking a trip through its centre. This was one of the motivations behind the Metavisionaries Academy summer program, which offers immersive classes in virtual reality on astrophysics & space exploration. The students, ranging from high school to undergraduate level, could join the class from anywhere in the world using either a VR headset, computer, or smartphone. Lectures were designed to harness the virtual space by bringing in models, exploring environments such as the Moon & Mars, and utilising 360° videos to offer a program that is not possible in a traditional classroom. We explore the challenges of moving from 2D presentations to creating a 3D experience as a lecturer, and how this can serve as a tool to reach people around the globe.



Talk link: <https://youtu.be/4UnbcHGH7UY>

There was a brief moment of darkness before the Metavisionaries Dome materialised around me. As the lights came up, I found myself standing in a room whose semi-transparent curved walls revealed a view of the Earth from orbit. The traditional staged seating of a lecture hall lined half the circular floor space, and a huge display filled the opposite side. This reminded me that I was not just here to admire the view!

Students popped into existence and spread out to find seats. My technical assistant for that day's class called across the room, "Hello Elizabeth! You're now co-host." I pressed a button on one of my hand controllers and brought up a tablet that allowed me to share my presentation on the display. We would start the lecture course here in the dome, but later take a trip through a stellar nebula, visit the surface of Mars, and tour the Trappist-1 exoplanet system.

This summer, the Metavisionaries Academy swung open its virtual doors to welcome students from around the globe to a wide variety of courses on space, astronomy, and frontier technology. All classes were hosted on "ENGAGE", which is a spatial computing platform where people can meet and interact in three-dimensional online environments.

ENGAGE is an example of a virtual reality or metaverse application. Once primarily considered the regime of gamers, virtual reality is now being used extensively to meet and work side-by-side with people anywhere in the world. Although wearing a virtual reality headset offers the most immersive experience, ENGAGE (or indeed, similar applications such as Mozilla Hubs, Spatial, Cluster, or VRChat) can be fully accessed via a personal computer or smartphone. Most students in my class used these latter options. Spatial audio (directional and fall-off with distance) in virtual reality spaces allows a natural in-person feel to interactions, and I found it easy to stand around and chat after the class with the students and other instructors.

The ten summer courses in the Metavisionaries Academy consisted of five one-hour classes each and were taught Monday to Friday. The classes were offered at a wide variety of times to accommodate students attending from different time zones and were aimed at teens as well as young adults. I designed a course titled "Water in the Universe" which looked at the distribution of water throughout our Solar System today, how this might have developed and changed since the formation of the planets, and what we know about water in planetary systems around other stars. I taught the complete course four times during the summer to different groups of students.

The core material for each of my classes was presented via a traditional PowerPoint presentation, which I supplemented with virtual models and experiences that took advantage of the metaverse. One of my favourite learning additions was the use of 360-degree movies. These could be displayed on a fully spherical screen surrounding the class, giving the experience of being "inside" the movie. YouTube supports 360-degree videos, and many educational and outreach videos have been produced by institutes such as NASA or National Geographic.

A second valuable addition was the use of three-dimensional virtual models, which were brought into the virtual classroom. Students could walk around, handle, turn and scale the models to allow a more hands-on experience that would be difficult to achieve even in a museum. I found this particularly useful in a class where I was describing the Hayabusa2 asteroid exploration mission. By importing a virtual model of the spacecraft, I could point out different aspects of the design and demonstrate the mechanism for landing on the asteroid surface. ENGAGE included many standard virtual models to be used in their facilities. Their additional resources included models from NASA and ESA websites for spacecraft and shared repositories such as Sketchfab. Models can also be designed using open-source software such as Blender. The Metavisionaries created many of their own models for exclusive use in the Academy. In total, there were around 300 separate models used in the 10 Academy summer courses.

During my lectures, we also took “field trips” to different environments, including the surface of Mars and the Moon, underwater, and a forest scene. Visiting these locations was a fun experience, and provided an engaging and memorable way to explore topics such as Martian science or engage in discussions about climate.

Teaching in the metaverse did have challenges. One issue is that avatars currently only offer limited facial expressions (although face-tracking is in development). The lack of expression made it difficult to judge if the students were confused unless they spoke up. To partially combat this, I used emojis to give quizzes. In ENGAGE, you can display emojis such as a smiley or surprised face, thumbs up, hearts, or stars above your avatars head. Students selected an emoji to choose an option from a multiple-choice quiz, which encouraged more interaction and feedback than requesting students to shout out.

As this is also new software, there were also technology issues. An update to ENGAGE over the summer temporarily broke the 360-degree videos for some users, and there were sometimes connection issues. I found it important to have back-up options, such as a copy of the regular 2D video if the 360-degree video did not play. It also took time to bring models into the classroom, or to switch scenes to a different environment or the 360-degree movie space. The lecture length therefore needed to be shorter than the equivalent in-person or zoom presentation, but with the benefit of more variety of media.

Overall, I really enjoyed the experience of teaching in the metaverse. I found the different ways of presenting material with slides, virtual models, immersive videos, and environments was an effective way to engage with the class and broaden the appeal of scientific topics. It is worth noting that while the classes were fully accessible via computer or smartphone, the best experience was with a virtual reality headset. The cost of headsets has tumbled in recent years, and the newly released “Meta Quest 3” standalone (no PC required) headset is retailing for about \$500 USD (and the previous model now being sold for about half that price). This might therefore be an interesting investment for schools and universities looking to expand their online program. Spending an hour in the metaverse each day, learning new and exciting topics is something that keeps attention and is a welcome break from a normal lecture classroom environment. I think it is something the students will look forward to.

Resources:

[Metavisionaries Academy website](#)

[ENGAGE](#)

[NASA 3D resources](#)

[ESA 3D resources](#)

[SketchFab website for sharing models](#) (some free, others paid)

[OmniScope](#) (designed the Hayabusa2 models)



Figure 1: My “Water in the Universe” class on the ENGAGE platform. My avatar is wearing a light blue hat and a jacket. We are discussing extrasolar planets and two possible worlds are floating in the air as 3D models: one is a tidally locked planet and the other is a lava world.

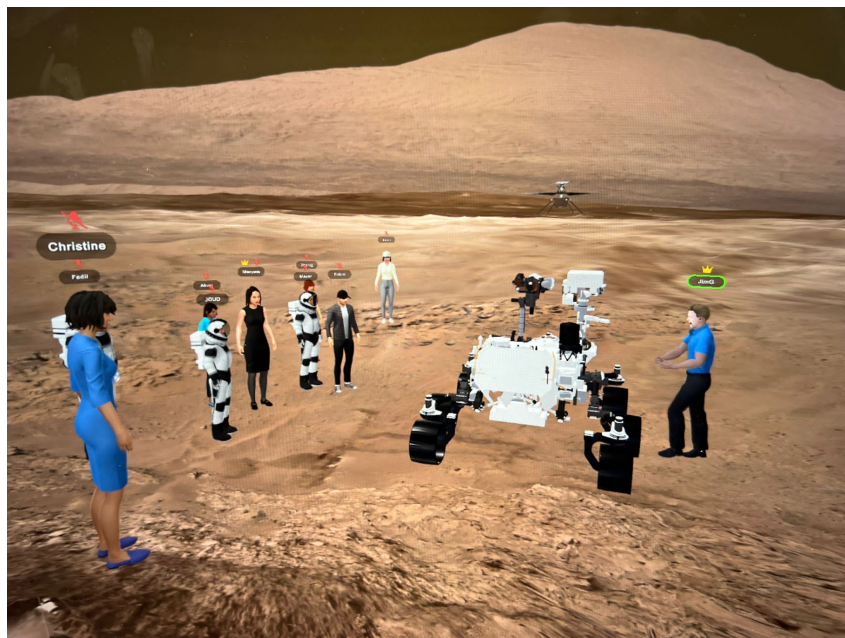
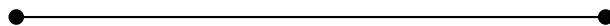


Figure 2: A scene from a Metavisionaries Academy class on Mars! Jim Green is describing the Perseverance rover and Ingenuity Marscopter. The virtual model is derived from 17 cameras on the Curiosity Rover.



Astronomy Teaching Through Astrocamps, Crafting, and DIY Astronomy Projects

Speaker: Ola Ali, National Research Institute of Astronomy and Geophysics, Egypt

In Egypt, Astronomy is neither a fundamental subject nor part of a science subject for most school years. Therefore, it is necessary to find new ways to disseminate astronomy knowledge to students. In this talk, I'll present the experience of teaching astronomy outside schools. Together with my colleagues at our institute, we organised many Astrocamps in the Kottamia Observatory, the Nature reserves, deserts, and even in youth clubs. We organised programs dedicated to different ages. We also organised workshops in Crafting and DIY Astronomy Projects to promote astronomy. These activities got the attention of students ages 5 to 12 especially. Also, we participated at the Cairo International book fair yearly since 2017 to introduce astronomy to the public and showcase our activities.



Talk link: <https://youtu.be/GYSoU248qx0>

As a member of the National Research Institute of Astronomy Geophysics (NRIAG), Helwan, Egypt, I started my educational activities with kids in 2013. In this talk I will present some activities me and my colleagues conducted to teach astronomy to kids.

All activities throughout the talk were conducted through the framework of the National Research Institute of Astronomy and Geophysics, as well as the Scientific Society for Astronomy and Space, Egypt Office for Astronomy Education, and Egypt Office for Astronomy Outreach.

In Egypt, astronomy is often not part of the core curriculum in schools. My institute "NRIAG," started a series of astronomy activities to disseminate astronomy knowledge to the public. These activities are part of the crucial social role NRIAG plays within society, through which we embarked on a mission to ignite the curiosity of students about the cosmos.

Astrocamps

Camps in general are beneficial on all levels. For adults, camps can be a relaxing vacation to enjoy the environment and meditate to overcome the stress of daily life or provide a time and space for parents to bond with their kids. Camps offer good opportunities to educate kids about survival skills, the environment, and what is important for us —Astronomy.

Dedicating a camp for astronomy can inspire and ignite a lifelong passion for science and exploration. During the astronomy nights in camps, the organisers will give the audience access to dark skies and unique stargazing experiences. Whereas the audiences will — mostly for the first time — explore the beauty of the night sky and observe celestial objects. The existence of small telescopes also provides new practical skills, ranging from setting up telescopes and observing with them to astrophotography.

In one example of such a camp in the desert, we arrived early in the morning, everyone engaged in setting up the tents, and then it was time for sandboarding, when the whole family could have fun and do a new activity. This camp was in a place called “Wadi al Hitan,” a valley of whales, which is a paleontological site located in the Western Desert of Egypt. It is recognized for its extraordinary whale fossil record. It is a UNESCO World Heritage Site that offers a unique glimpse into the ancient history of these incredible creatures. The families had a tour there with a Geology guide to explore some of the fossils. At night, the time for astronomy activities began. We observed the sunsets and talked about the movement of the Sun and the Earth. We set up two small telescopes; at first, we started exploring the sky with our naked eye and then observed whatever celestial objects we could find in the sky (moon, planets, nebula). This camp coincided with the Perseid meteor shower and a clear view of the Milky Way, so it was a perfect time for priceless memory photos with the Milky Way.

One of the most famous astrocamps in Egypt is the Kottamia Astronomical Observatory, one of NRIAG observatories, where we welcome families, individuals, schools, and universities to spend an amazing astronomical night at the observatory.

Sometimes these astrocamps are too expensive, too far, or too difficult to attend for any other reason, so NRIAG held many stargazing nights with portable mini astrocamps. Some of the researchers went to public places in the city (library, youth club, historical places), set up the telescopes, and observed the sky with the public for a few hours after sunset. NRIAG has held many stargazing nights all over Egypt, including the monthly event in the Child Museum.

Models and Crafting

Being engaged in hands-on experiences fascinates students of all ages and inspires young minds to explore the cosmos. This is especially the case, when engaging with children between the ages of 5 and 12.

1- celestial sphere, constellation projection (Figures 1 and 2)

If the kids can't be in an astrocamp or stargazing event, they won't be able to have a clear vision of the sky. A model for the celestial sphere is a good tool to solve this problem. We already have a celestial sphere inside NRIAG's museum and when we are outside NRIAG, we use a portable celestial sphere with a diameter of around 15cm. It works as a tiny planetarium but makes a convenient demonstration of star movements. As part of exploring the sky without being out, crafting a constellation projection becomes helpful. For this, we need A4 cardboard to make a tube, two b5 white paper to make a cover, an elastic band to attach the white paper on one end of the tube, a toothpick to make holes in the white paper, and a flashlight. After assembling the tube, we asked the kids to make some holes into the first sheet of white paper to create whatever shapes they wanted (heart, letter,..., etc). Then, we had some famous constellations printed on a small scale so the kids could use it on the second white paper. By pointing the flashlight inside the tube while dimming the lights of the room, a projection of the holes will be



Figure 1: Portable celestial sphere with diameter around 15cm.

visible on the wall.

2- Sun, Earth, and Moon model (Figure 3)

In NRIAG, Dr. Mohammed El Sadek created a model to show the Sun, Earth, and Moon movement and how the eclipse happens. We use this model in almost every event inside or outside NRIAG, because it's not that heavy to carry.

For younger ages, it's better to let them be engaged in more fun activities than only watching moving models. We provided the kids with white paper that had a drawing of the Sun, the Earth, and the Moon. We also gave them two rectangular shapes, and asked them to color the paper, cut the shapes out of the paper with caution, and assist those who couldn't use scissors to cut out these shapes. Finally, we assembled the shapes together to create the model.

3- Moon craters

In this experiment, we tried demonstrating to the kids why the surface of the moon has impact craters. We used white cement, water, and rocks to make a dough of the cement. We then asked each of the kids to throw a rock at it from different positions with varying force.

Science 2017 NRIAG participated yearly in the Cairo International Book Fair where we welcomed visitors for 2 weeks in our booth. At our booth, they were able to get astronomical books, talk to astronomers, and most importantly be engaged in hands-on projects to ignite curiosity and foster deeper understanding of astronomical concepts.

All Our previous activities and other efforts have been driven by a simple idea: to make astronomy accessible to all. Finally, all this work couldn't be done without the magnificent Egypt-NAEC team members and every other member of the institute.

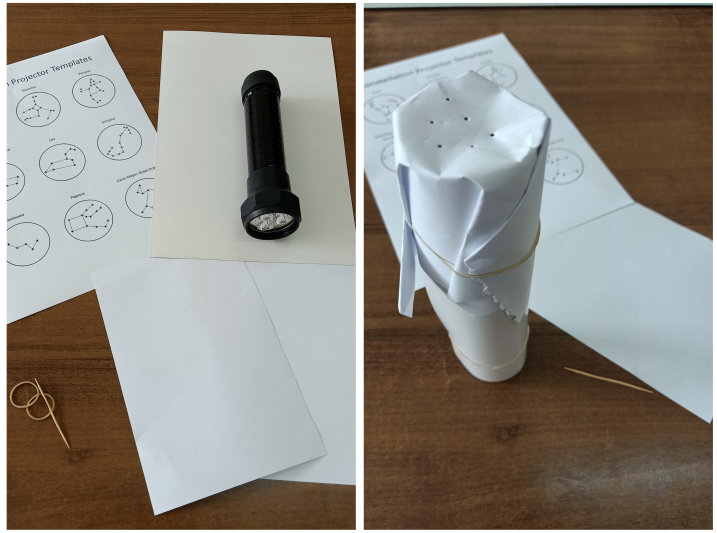


Figure 2: On the left, you see the tools used to craft the projector. On the right, the assembled projector is shown.

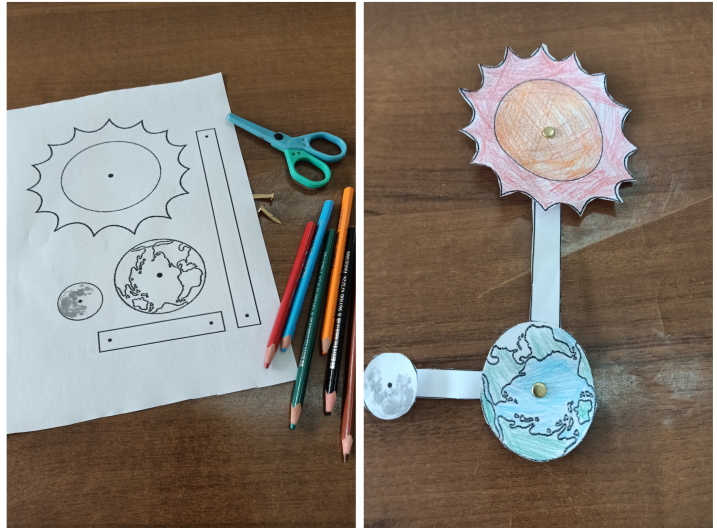


Figure 3: The Sun, the Earth, and the model before and after assembly.



Outdoor Practical Astronomy Education: OAE-Egypt Projects

Speaker: Somaya Saad, National Reserch Institute of Astronomy and Geophysics, NRIAG, Egypt

We would like to share the main projects of the OAE-Egypt in the field of practical astronomy education. We implement astronomy education outside the classroom using various tools and practices: 1- Virtual Reality (VR) is utilized as a powerful educational tool that can change the way students learn about astronomy. By providing experiences and simulations, VR enhances their understanding of astronomy. 2- Desert trips and night camps are organized for observing planets and stars in the sky. 3- Planetarium shows, screening astronomical programs are organized. 4- Tourist astronomy is promoted to maximize the benefits of Egypt's architectural astronomical heritage. Tourist astronomy helps spread the basic concepts of astronomy across a wide range of Egyptian cities.



Talk link: <https://youtu.be/yVzA3ztkLZw>

Outdoor practical astronomy Education: OAE-Egypt projects

Recently, we have observed a rapid growth of public engagement in astronomy outreach, accompanying various initiatives of IAU offices promoting astronomy education and outreach. Astronomy activities outside the classroom are among the most important because they can reach everyone directly. We would like to share some ideas for astronomy education outside the classroom setting.

Virtual Reality, VR

Virtual Reality is a powerful educational tool that can be used to change the way students learn by providing experiences and simulations that enhance their understanding of astronomy. VR can provide students with a safe and well-controlled environment to practice and improve their skills, preparing them for future space exploration. Using VR, students can benefit from the scientific and technological progress in communication and information technologies.

Remote learning

After the Covid-19 pandemic, during which safety instructions had to be followed and classroom education was rendered impossible, distance education emerged as a necessary means to continue and complete the educational process. Even after the end of the pandemic, distance education enabled teachers to communicate with a greater number of students. It also allowed a large number of students to participate in various astronomical activities and webinars together.

This way, the students could access astronomical resources and prerecorded astronomical material remotely.

Astronomical Phenomena

Tracking astronomical phenomena is an interactive approach to teaching the fundamentals of astronomy. The various movements of objects within the Solar System — including orbital movements with their inclinations and rotations at different levels and periods — give rise to a multitude of phenomena. Solar and lunar eclipses, meteor showers, and planetary conjunctions stand out as some of the most significant phenomena that can be observed and studied.

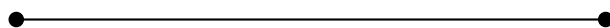
The Planetarium

The Planetarium screens projections of a 3D panorama of the sky, celestial bodies, and various astronomical phenomena. The planetarium shows can thus serve as an educational tool, teaching spectators celestial navigation techniques and enabling them to learn about the wonderful discoveries in astronomy and space exploration. As such, planetariums play a crucial role in enhancing the knowledge of astronomy in an interactive way.

Astro Tourism

Tourist astronomy serves as a valuable tool for astronomy education in various respects. It allows us to maximize the benefits of Egypt's architectural astronomical heritage. Moreover, many Egyptian cities provide ideal settings for observing and learning about the fundamentals of astronomy simply by enjoying the night sky. Furthermore, students can continue their astronomy education even during vacations through night camps.

Outdoor astronomy education can also be facilitated through various other means such as Astro programs, Stellarium, sky map, Astro Trips and Camps, Astronomical Museums, and events like the Cairo International Book Fair, etc.



Gee-Whiz Astronomy Modelling – a Worldwide Online Club Opening Doors to Astronomy Research

Speaker: Fraser Lewis, Faulkes Telescope Project, Global Hands-On Universe,
GWAM, UK

Gee-Whiz Astronomy Modelling (GWAM) works with students, teachers and scientists to develop open-ended (research-style) astronomy projects. Participants live and study in Chile, India, the United States and Wales and collaborate online synchronously for one hour every week at a time manageable to all (typically Fridays ~ 18 – 20 UT). Teachers and students alike learn how to collect and analyse astronomical images and datasets, use and develop skills in free astronomical software, code in Python, and explore astronomical catalogs, such as Gaia’s DR3 and the interactive data viewer and editor, TOPCAT. Students work both independently and collaboratively – transiting exoplanets, eclipsing binaries, and open clusters are all currently areas of active study with papers in preparation.



Talk link: <https://youtu.be/UgNVnGprUn0>

I present GWAM, an online astronomy ‘club’ giving students, teachers and educators worldwide access to astronomical research and researchers. Gee-Whiz Astronomy Modelling (GWAM) was founded during the pandemic by Carl Pennypacker (UC Berkeley, GHOU) and Elizabeth Villanueva (University of Chile) to develop open-ended (research-style) astronomy projects for students.

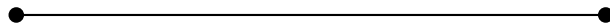
Participants live and study in Chile, India, the United States, Colombia, Argentina, and Wales and collaborate online synchronously for one hour every week at a time manageable to all (typically Fridays ~ 18 – 20 UT).

Teachers and students alike learn how to collect and analyse astronomical images and datasets, use and develop skills in free astronomical software, code in Python, and explore astronomical catalogs, such as Gaia’s most recent catalog DR3 and the interactive data viewer and editor, TOPCAT (<https://www.star.bris.ac.uk/~mbt/topcat/>).

Students are also able to take advantage of a generous allocation of observing time from Las Cumbres Observatory, providing them with an opportunity to collect and analyse their own data.

Students work both independently and collaboratively and very often are ahead of their teachers and supervisors in finding appropriate tools, techniques and datasets – transiting exoplanets, eclipsing binaries and open clusters are all currently areas of active study with papers in preparation.

We are currently developing a four stage set of resources for teachers and students to use independently of our online meetings and are always on the lookout for new participants. Find out more at our website, <https://sites.google.com/view/gwamcl>



ES Astronomy Exhibition

Speaker: Julio Fabris, Federal University of Espírito Santo, Brazil

The ES Astronomy Exhibition (MAES) consists of the preparation of works on astronomy with possible connections to related areas by primary and secondary school students, under the guidance of a tutor-teacher. The works are evaluated by professors and researchers working in Physics and Astronomy. MAES seeks to cover the entire state of Espírito Santo. At the end of the Exhibition, students and teachers of the best classified works were awarded scholarships to continue proposed projects under the supervision of university professors, specially UFES. Thus, MAES also seeks to promote student leadership and create an environment of integration between Basic Education and Higher Education.



Talk link: <https://youtu.be/0bKDPmC46Yw>

The Espírito Santo Astronomy Exhibition (Mostra de Astronomia do Espírito Santo - MAES) aims mainly to promote the dissemination of Physics and Astronomy among students and teachers of basic education (elementary and secondary) in the state of Espírito Santo, Brazil, encouraging them to develop these areas of knowledge. This event is organized by the Federal University of Espírito Santo (Universidade Federal do Espírito Santo- UFES) through the Astrophysics and Cosmology Center (Núcleo Cosmo-ufes) and the Federal Institute of Espírito Santo (Instituto Federal do Espírito Santo- IFES), in particular the Guarapari Astronomic Observatory (Observatório

Astronômico IFES-Guarapari - OAIG). MAES is an organisation that facilitates the presentation of projects related to Astronomy, which must be produced by basic education students under the guidance of their teachers. Any students duly enrolled in the ninth year of elementary school or high school, in public or private schools in Espírito Santo, may participate.

In 2024, we will have the seventh edition of MAES. In five of the previous editions (2018, 2020, 2021, 2022, and 2023), we counted on resources from the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq) to carry it out. The 2023 edition has recently concluded. In particular, CNPq has provided support in the form of resources for the execution of the project, in addition to Junior Scientific Initiation scholarships for students and Monitoring Scholarships for the professors who supervised the award-winning work.

Each edition of the event typically receives approximately 100 registered works, most of them (about 90%) from public schools. The total number of participants is of the order of 500, coming from all regions of Espírito Santo. It must be remembered that this state has about 4 million inhabitants.

The organization of MAES spans almost the entire calendar year and consists of the following stages.

- At the beginning of the academic year, the organizing committee launches the public notice about the MAES and is responsible for publicizing it. Students interested in participating have to identify a mentor professor (this, in turn, must be a professor, preferably, from the institution where the students study) and register their projects on the event website. Each project must have: a guiding teacher, up to five students (we stimulate gender balance in the groups, such that large groups must preferably contain at least one girl) and the main theme must be Astronomy, Astrophysics, Astronautics, or Cosmology. The presentation of the work consists of three phases, the first being purely remote, and the last two in person.

- i. In the first phase, all registered works must send a summary and an explanatory video of the project, lasting a maximum of 5 (five) minutes, by the date stipulated in the released schedule.

These videos are made available on the MAES website to engage the wider community. If applicable, the community may evaluate the videos through a provided link during the event.

A committee watches and evaluates the registered videos. At a scheduled date and time, they engage in discussions with the registered groups regarding the submitted videos and summaries. The first phase of MAES is eliminatory. Only those works that do not suit the purposes of the event are disqualified, as they do not have an academic-scientific or educational character. This stage also allows for discussion between the organizers and the teams of the registered works.

- ii. During the second phase, the works are presented orally, in one of the three centers, one in the north of the state, another in the central region, and another in the southern region. The works are presented in a seminar format and last for 15 minutes before an evaluation panel composed of invited professors with outstanding relevance in the scientific world. This phase of the MAES is a two-day event. It is intended that at least one of these stages takes place during the National Science and Technology Week (Semana Nacional de Ciência e Tecnologia - SNCT).

In parallel, the community has access to scientific dissemination lectures and mini-

courses, covering current topics in Physics, Astronomy, Astrophysics, and Astronautics, all taught by guest professors. In addition, there are other activities such as workshops, night sky observation, mobile planetarium sessions, and educational games.

During the second phase, 15 works from High School and 3 from the ninth year of Elementary School are selected, which move on to the third phase.

- iii. The third phase of MAES typically takes place at the OAIG (IFES, Guarapari) and is also an in-person event, lasting two days. However, in exceptional cases, remote transmissions will be accepted for presenting work. During this stage, students present the results obtained in their work, improvements, and advances from the initial registration to its final version. For the presentations, a time of 20 min is reserved to each team. In this final stage, scholarship holders are selected for the following year in order to develop specific work plans under the supervision of members of Cosmo-ufes and OAIG.

- All students and teachers participating in the **Exhibition** receive certificates, whereas the best works receive medals. Furthermore, twenty students and five teachers are selected from among the works presented in the third phase to receive ICJr and ATP-A scholarships, respectively. The scholarships are available thanks to CNPq support and the denominations follow the CNPq classification. The selected works also receive financial assistance to participate in the next edition of the *Espírito Santo Astronomy Meeting* (Encontro de Astronomia do Espírito Santo), an annual event promoted by Cosmo-ufes. Furthermore, the results obtained may be published in the magazine *Cadernos de Astronomia*, published by Cosmo-ufes. This also aims to develop the practice of writing scientific papers among primary school students and teachers.

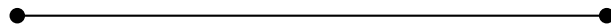
Fellows are invited to participate in actions linked to Cosmo-ufes and OAIG, such as training events at OAIG itself. This group may, optionally, be joined by up to 8 students from better-ranked private schools. These training events include seminars, mini-courses, and astronomical observation sessions. Participants learn how to handle simple telescopes and obtain astronomical images with the aid of CCD cameras, image processing, spectroscopy, etc. Students are also encouraged to develop activities to promote Astronomy among rural communities surrounding the chosen region.

- Students from 1^o to 8^o years of Elementary School participate in the Event in a special category called “MAESinha”. All students registered in this category are awarded medals. This is a non-competitive, parallel activity to the MAES itself.

The videos produced by MAESinha participants must involve themes that encourage observation of the sky and interest in science in general.

Actions to popularize science are carried out during the two final phases of MAES, stimulating critical reflection, scientific curiosity, scientific reasoning, and the capacity for innovation. These actions involve: lectures on topics related to Astronomy given by researchers in this area of knowledge; mobile planetarium sessions; night sky observation workshops; observation of the sun and night sky using telescopes; presentation of projects developed by primary school students, among others. These free events are made available to the entire community present at the event location. The event encourages the sharing and socialization of scientific knowledge through free actions open to the community. These include the exhibition of works and experiments, which among other formal and non-formal teaching tools undoubtedly contribute to generating social transformations, reducing inequality and assisting human development in the regions visited by MAES.

Presentations of work in the in-person phases are open for the community to participate (directly and indirectly) in MAES. At the end of each explanation, a debate session is opened. Thus, the exchange of experiences between the students participating in MAES and the school community present at the presentation is promoted, encouraging cooperation, solidarity, and healthy competitiveness.



The Travelling Telescope

Speaker: Susan Murabana, The Travelling Telescope, Kenya

The Travelling Telescope is a social enterprise dedicated to promoting science and technology using astronomy tools and concepts. We take our computerised portable telescope and mobile planetarium around Kenya and Tanzania, educating the public about our universe and emphasizing the importance of protecting our fragile planet. We focus on two main areas, Education and Tourism. We are the youth partners of Airbus Foundation and have successfully completed robotic workshops with them. In addition to this we have delivered online 3D modelling workshops using Tinkercad, a product of Autodesk. We also recently built a permanent planetarium with the dome built out of bamboo. This is the only permanent planetarium in East Africa.

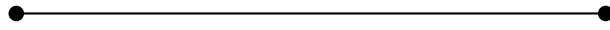


Talk link: <https://youtu.be/44aUF18FVa4>

We have reached hundreds of schools and hundreds of thousands of students in city and rural areas of Kenya and Tanzania. We have been featured on CNN, BBC, Aljazeera, and many other local and international media houses. Please visit our website for more information: www.travellingtelescope.co.uk

Our primary goal is to establish the Travelling Telescope project in schools across Kenya and the rest of Africa in an effort to confront the deficit of research-based education in Africa. Astronomy is a science that sparks curiosity and intrigue, and through our project, we hope to

excite young Africans to love science and explore their environment using the scientific approach. By providing our tools and expertise as complementary to the school curricula we are exposing our young minds to a different, interactive and exciting way of learning science.



Closer to the Sky: Co-Creating Astronomical Knowledge in a Favela of Rio de Janeiro

Speaker: Maria Clara Heringer Lourenco, Universidade Federal do Rio de Janeiro, Brazil

Collaborators: Arianna Cortesi, Gabriela Rufino Travassos, Claudia Mignone, Cláudio Alberto Barbosa Araujo

The Closer to the Sky initiative fosters astronomy awareness within Brazilian “favelas.” It harnesses astronomy’s potential to uplift underprivileged children. Since 2022, educational sessions occur at the communal “Ninho das Águias” library, built by Pavão-Pavãozinho residents in Rio’s PPG complex on a former landfill. The project offers physics experiments and interactive games, aiming to propel youth growth through captivating astronomy. This outreach fosters inclusion, valuing community knowledge. It provides support and protection for PPG’s children, nurturing their well-being.



Talk link: <https://youtu.be/hiwsncl1gr8>

Closer to the Sky is a project that aims to co-produce scientific knowledge through collaboration among astronomers and artists/educators living in the PPG favela. It is designed for the children, teenagers, and young adults of the community. We work in close collaboration with the social project ‘Ninho das aguias’, where classes are being held.

Favelas in the state of Rio de Janeiro are often located on hills, serving as a refuge for formerly enslaved people after the abolition of slavery in 1888, as well as for immigrants who worked for downtown citizens. The Law of Lands (1850) prevented unoccupied lands from being owned through labor and provided government subsidies for the arrival of foreign settlers to be hired in the country, further devaluing the work of black men and women [1]. As a result, favelas

today are mostly composed of a black population, surviving decades of persecution and low income while defending, preserving, and creating a unique culture rooted in African origins that reverberates into music and the arts. These populations still struggle with problems rooted in colonization. Even today, a black youth is killed in Brazil every 23 minutes [2]. This figure alone indicates how Brazil is still a country of great inequalities.

Statistically, children in favelas, due to social and economic inequality and racial discrimination, have less possibility of personal development and professional realization. They attend public schools where, according to SAEB [3], students did not reach a satisfactory level in Portuguese language (69%) and math (95%) in 2021. They hardly have access to after-school courses and do not tend to see themselves represented in the academic community. This produces a disadvantage in access to higher education and consequently in opportunities for decent employment. Offering extracurricular courses and cultural experiences to students in the PPG, we aim to enrich their school curriculum and strengthen the chance that they will wish to continue their education after secondary school. A key element of the courses is providing positive role models of scientists from Afrodescendant backgrounds, reinforced by the presence of local artists and educators, thus endorsing their role within the academic community.

The project also creates decent work opportunities for local artists and educators. They will offer workshops rooted in favela culture while simultaneously developing novel, decolonial courseware based on contextualized science. This includes materials that use the context of marginalized societies as examples through which we can better understand, learn, and make science.

The PPG complex is one of the city's oldest favelas: it dates back to the early 20th century when it was occupied by formerly enslaved people and immigrants from the countryside and the northern parts of the country. Therefore, its origins are directly linked to the heritage of slavery in Brazil's society. Located between three of the richest neighborhoods in Rio, it was unable to expand territorially, leading to one of the city's most densely populated favelas. One-third of the population consists of young people (15-29 y/o) [4]. As in most favelas, development indicators such as literacy and income above minimum wage are considerably below the city average. The neighborhood children have hardly any access to extracurricular courses beyond public school and fewer opportunities for personal development and professional realization. From an early age, they are exposed to scenes of violence, encounter heavily armed people, and endure economic and psychological difficulties. This produces a disadvantage in access to higher education and reduced access to decent work opportunities. Due to its historical and current roots, as well as its socio-economic status, the favela environment is permeated by a vibrant, unique, and resilient culture. Art is a way to preserve identity, find decent work, and achieve economic growth for the family. However, the favela culture is still marginalized and restricted to specific areas, resulting in very few cases of collaboration with the academic environment. Moreover, artists and culture promoters in the favela are often underpaid and excluded from university grants. Our main goal is to build bridges, bringing science dissemination and education into the territory of a favela in Rio de Janeiro, and inviting local people to join and co-create scientific content.

The material developed within the project will be shared as Open Educational Resources. Moreover, new work opportunities will arise as five of the oldest students will be trained as astroguides in collaboration with Astronera[5]. Their training will benefit from visits and courses at the



local Planetarium and Museum of Astronomy. The activity of certified astroguides from the favela —promoting cultural astronomy, love for the dark skies, and a scientific culture on Rio's iconic Arpoador stone (among other places), where people from the favela generally earn their living by selling food and souvenirs —will be a small but significant step toward building a fairer tomorrow.

References:

- [1] <https://studentsforliberty.org/brazil/blog/como-a-lei-de-terras-perpetuou-a-opressao-dos-negros/>
- [2] https://flacso.org.br/files/2016/08/Mapa2016_armas_web-1.pdf
- [3] <https://www.gov.br/inep/pt-br/areas-de-atuacao/avaliacao-e-exames-educacionais/saeb/resultados>
- [4] https://wikifavelas.com.br/index.php/Pav%C3%A3o-Pav%C3%A3ozinho-Can tagalo,_o_PPG
- [5] <https://www.astronera.org/>



A Week in the Life of a 15-Year-Old Astrophysicist

Speaker: Stephanie Bernard, University of Melbourne School of Physics,
Australia

Students in high school in Australia undertake five days of work experience in any field, most commonly while in the 10^o grade. The astrophysics group at the University of Melbourne has hosted these students since the 1990s, evolving from a handful of students each year into a structured program that hosted over 30 students in 2023. These students attend regular talks and colloquia in the astrophysics group, along with classes on different techniques in astrophysics, and complete their own short research projects. Their work leads up to a final poster session with students in other science areas. I will discuss the evolution of this program, the outcomes for the student workers, and the benefits of the program to the university community.



Talk link: <https://youtu.be/3zDT5cJUwhI>

In secondary school in Australia, students are expected to do a 5-day “work experience” placement at a business. This usually occurs in years 9 or 10 (equivalent to US high-school freshmen or sophomores), who are 14-16 years old. This program is designed to give students an idea of what working in a particular career entails, by shadowing staff for the five days of the program. Students are expected to find their own placement, with assistance from their high school, who may run careers classes in years 9-10 to prepare students for the placement.

Many businesses and government organisations run a special program for these students, and the University of Melbourne (UoM) School of Physics has been running a work experience program for year 10 students since the 1990s. This program has evolved over time and is currently administered by the UoM Faculty of Science, which runs work experience programs over several Schools and Departments in science. In 2023, the week-long program ran from June 19-23, during the last week of the school term before the students’ winter holidays.

In the School of Physics’ program, the schedule for the week is organised into several streams, each sponsored by an Australian Research Council Centre of Excellence (CoE) based in the school. In 2022 and 2023, these streams were astrophysics with the CoE for All-Sky Astrophysics in 3-Dimensions (ASTRO-3D), particle physics with the CoE for Dark Matter Particle Physics (DMPP), and biophysics with the physical bioscience group. Prof. Elizabeth Hinde from the biophysics group was the faculty coordinator for the program, whereas I coordinated the astrophysics stream. In 2023, no particle physics coordinator was available, so this stream did not run.

I was a work experience student in the astrophysics group in 2006 and enjoyed my time immensely. When planning the program I am very keen to keep the same sense of wonder that I experienced, but when planning a program like this at a university, it is very easy to make the experience one of “being a university student,” rather than “being a working physicist.” To combat this, we revamped the program in 2022 to have a stronger focus on individual and group research time for the students. The program in 2020 and 2021 occurred during Melbourne’s COVID lockdowns, providing us with an opportunity in 2022 to take a new direction more easily.

The first thing to take into account when planning the program is the time the students will spend with the Faculty of Science at the beginning and end of the program. In 2022, this was half of the Monday and all of the Friday, leaving 3.5 days for physics content. In 2023, the Faculty had the students for just half of Monday and half of Friday, providing us with a bit more time. On Friday, students from all of the different schools came together for a poster session, where they talked about the research projects they have done during the week. With this constraint, we wanted all the project time to be finished by Thursday afternoon, so that the posters could be printed. We also took the students on a traditional trip to Melbourne Planetarium on Thursday afternoon to see the full-dome movie ‘Capturing the Cosmos’, which features science from UoM astrophysics.

Next was finding a balance between attending talks, practical sessions, and their project time. There are several weekly talks in the astrophysics and School of Physics schedules, like group meetings and colloquia. We wanted the students to attend these as much as possible, however, the astrophysics colloquium did not run in the week of 2023, so students attended the astrophysics weekly meeting on Monday afternoon. This followed their induction tour of the Physics building, and afterwards we spent time talking about their research projects.

In total, 47 students joined the Physics program in 2023, with 30 choosing astrophysics and 17 choosing biophysics. Two supervisors were employed by ASTRO-3D (myself as coordinator, and Doran Huh, a former MSc student in the astrophysics group) for the five days of the program. We also recruited volunteers from the graduate students in the astrophysics group to assist with laboratory exercises and help with the students’ research projects. Biophysics also employed three PhD students to assist with research projects in their stream, as they would be using more complicated equipment.

The astrophysics research projects were designed to be open-ended, with students given a 2-3 sentence description of an idea, and encouraged to use whatever lab equipment they wanted to investigate the idea. Some of these were:

- Using a glass model of a gravitational lens to model magnification of light
- Using a spectroscope to measure the temperature of the Sun
- Using an orrery to model exoplanet transits and calculate their properties

We also used an existing Python code used by third-year physics students to model black hole orbits for students who were more interested in coding. We also have a backlog of observations by first- and third-year Physics students, taken using iTelescope telescopes. Students could download some of this data and analyse the stars and galaxies in them for their research.

An outcome of these research projects for the astrophysics group was that these students were a great ‘test group’ for developing new lab exercises for first-year astrophysics classes.

These first-year university students are not expected to have taken year 11-12 physics, and the prerequisite is a year-10 level of mathematics study. Seeing how the work experience students used the equipment to investigate the problems gave us an idea of how the first-year students would also do the experiment. Two of the experiments were developed into 3-hour first-year lab exercises in 2022-23, based on the work of the 2022 work experience cohort. These were the spectroscopy of the Sun and the model exoplanet, as they fit nicely into our existing first-year astrophysics courses. The work experience students were also the first to look into data that we collected of the May 2023 supernova in M101, which will become an observational lab for third-year students.

The research project time was complemented by laboratory and programming classes, to give students some idea of how to do experiments in the labs before starting their own investigation. We chose two first-year astrophysics labs, one on spectroscopy of gas emission lamps and black body radiation, and the other on 'geometry on a sphere', where the shape of lines and triangles on a balloon surface is explored. The spectroscopy lab was useful for both astrophysics and biophysics streams, and also for many different areas of science. The geometry lab was intended more as a 'fun' lab, that would also develop some mathematical intuition in the students.

The programming lab was run for all Physics students by Doran Huh, using Software Carpentry's introduction to Python exercises. Students in Australia are often exposed to programming concepts in junior and secondary school, but in abstract ways (using Spheros or similar programmable robots). In 2022, we used a more child-focused introduction to Python exercise, but the students completed this very quickly, so we got them to follow on with the Software Carpentry exercise. They were very interested in this as they got to do some 'real coding', so in 2023 we skipped the children's exercise. Doran set up an Anaconda in the Cloud session so that students could download the data used in the exercise easily and set up their own coding environment in a web browser. They could then use this environment to complete the black hole research project if they wanted to.

We also had a talk program delivered mainly by PhD students in physics. All students attended these, and they covered astrophysics, biophysics, and particle physics. When I organised the program in 2016, I wanted to cover many areas of astrophysics and had 12 30-minute talks during the week. In 2022 and 2023, we cut down the number of talks, recognising that the hands-on experience was more valuable for the students. We had 7 40-minute talks, with time at the end for students to ask questions, and encouraged the speakers to discuss their careers as well. On Friday morning, we also held the "Physics Show", a mainstay of the School's outreach program. This was run by Prof Roger Rassool and Steven Damen, and was originally scheduled on Monday as part of the School induction. On Friday, the students were much more familiar with each other and the time change ended up being a benefit, as they were happy to get involved and use the knowledge they gained during the week to discuss the demos shown.

Our graduate student volunteers were less numerous than in previous years, as the work experience week often coincides with Australia's national astrophysics conference, the Astronomical Society of Australia's Annual General Meeting. In 2022, they helped with both lab exercises and research supervision. However, in 2023, we asked for their help mainly with the research projects and in giving talks. This supervision time is good professional development for the graduate students, both in practising science communication skills and in developing mentoring skills that they will need in a career in physics. As everyone has a different career path in physics,

this also gives the work experience students an idea of the many ways they can do physics.

Part of the work experience program is for the supervisor to evaluate each student's performance during the week. I took on the paper evaluations, while Prof. Hinde completed email evaluations. All students were evaluated as very good, showing aptitude in technical and research skills. The Faculty of Science also received evaluations on the program from the students, and Physics was rated on average 8/10 for overall experience by the students. Most students said their interest in STEM had increased, though not necessarily in physics. Student feedback was for fewer talks and more experiments, which will be taken into account for the 2024 program.



Amateur Astronomers Adjust Engagement Styles for New Generations

Speaker: Vivian White, Astronomical Society of the Pacific, USA

Collaborators: Theresa Summer, Astronomical Society of the Pacific; Pamela Harman, SETI Institute; Jean Fahy and Jessica Henricks, Girl Scouts of Northern California

While many amateur astronomers in the US and the UK were inspired by the Apollo space race of the 1960s, the educational landscape has changed dramatically since then. As the local link between astronomers and the general public, astronomy enthusiasts can learn much from the latest pedagogy research. Reaching the broadest audience has great implications for the future of astronomy - both as a hobby and a career. In this session, you will discover 3 simple tips and learn where to find additional information.

Talk link: <https://youtu.be/PL0BkmCZk40>



Amateur astronomers in the US volunteer thousands of hours each month, directly interacting with informal learners of all ages, and sharing their celestial awe and knowledge. They contribute

to public awareness of major sky events from meteor showers to eclipses. From guerilla sidewalk astronomy to serious scientific lectures, they act as the bridge between an interested public and professional astronomers. For little more than the joy of hearing “ooooh, wow!” at a peek through their eyepiece, these dedicated sharers of wonder continue for decades in this delightful hobby.

In the US (as well as the UK), the amateur astronomy community skews towards members over 50 years old and more than 80% male by many estimates. In addition, astronomy clubs outside of major American metropolitan areas are predominantly white, their members are more affluent and hold a more traditional education on average than the community as a whole. These demographics closely mirror other hobbyists from beekeepers to homebrewers.

While many of these astronomy enthusiasts became enthralled with the night sky during the Apollo space race era, the school systems and communities in which they were educated were radically different from today's – constitutionally or socially imposed segregation was a fact of life, with strict gender and class roles enforced from the 1950s well through the 1970s. Educational philosophies of the time placed a necessary emphasis on memorization and following directions, preparing students to enter a mechanized workforce. For many reasons, less than half of the students graduated from high school. Students who succeeded in this system went on to become many of the scientists of their generation, transitioning from studious pupils to become the next “sage on the stage” themselves.

Today, both society and schools reflect different values. An emphasis on student-centered learning, critical thinking skills, and active engagement creates an environment where more students are able to succeed. In addition, an emphasis on Science, Technology, Engineering, and Math (STEM) subjects reflects the current need to prepare students for an increasingly technology-driven world. With better encyclopedias at our fingertips than the best school library could contain, memorization is no longer paramount, and critical thinking is the skill to cultivate. Students expect a more engaging curriculum beyond textbooks and multiple-choice tests. The stage has changed.

However, the curiosity that inspires connection and interest in astronomy remains the same. Rather than lament the shift away from a rigid and rigorous single path, let's embrace these differences and learn from each other with genuine curiosity if not always understanding. If our goal is to inspire a broad range of interested people, it can change the way we approach outreach. Young visitors to the telescope often have their phones out, which can hinder the eyes' ability to adapt to darkness; visitors to an observation site need to be aware of this. However, if you're on a school playground or a city sidewalk, public outreach has the ability to reach a broad audience, phones and all.

The astronomers of the past century were innovative and made groundbreaking discoveries that inspire us all. However, they were not inherently smarter than anyone else in the room. The demographics of Western scientists reflect access to education, instruments, and time that the majority of the population could not afford. It also reflects generations of gate-keeping in the sciences, both intentional and not.

The challenge and joy of living in this time is that we are able to change this with our direct action. While the institutional “-isms” will take time to adjust, meaningful engagement with

diverse audiences —the interpersonal work —can happen right now. I challenge you to try one of these methods the next time you do outreach at your telescope, at a school, or with the person sitting next to you on an airplane.

The first challenge is simple – instead of starting with what you think is fabulous about space, start by asking your visitors a question. It can be really simple. If you're at your telescope, ask, "Have you ever looked through a telescope before?" This allows them to share something about themselves and gives you a better idea about where to start a conversation. It also reduces the risk that we will make assumptions about a person based on what they look like, their age, gender, or race. We all have biases based on our lived experiences. They are important to recognize and what's even more important is what we do about them.

My second challenge to you is to learn a new story. We all know about Hubble, Newton, and Einstein. They made incredible contributions to astronomy and their names have gone down in history. We are also slowly beginning to honor others who made contributions – Chandra, Leavitt, Rubin. These stories are important. I challenge you to think of a story that you tell regularly during outreach and find someone new – a woman or other underrepresented person in astronomy. When I show Saturn's rings, I now tell the story of the Queen of the Rings – Dr. Carolyn Porco who led the imaging team on Cassini mission.

On a walk with a friend the other night, the Moon looked huge on the horizon. She asked me how far away it was. Now, I use that number all the time. But, do I have it committed to memory? – Nope. I look online for a trusted source. So instead, I said, "I don't know. But I bet we could figure it out together. I know about 30 Earths could fit in the space between the Earth and the moon. Do you know how wide Earth is?" We thought about it for a while as we walked, and she knew how wide the US was, so we over-estimated Earth to be about 10,000 miles across.

That would put the Moon around 300,000 miles, or 500,000 km away. Will she remember that number? Probably not, we thought. Neither one of us had any real concept of the distance of hundreds of thousands of kilometers. What she wanted to know was how close the Moon was to us. Imagining 30 Earths in a line gave her a better idea than a number ever could.

In fact, it's actually closer to 400,000 km, but what she understood was how I might – how she might - figure something like that out. This is something we did learn in school – show your work. And if you don't know something, that's ok too. Sharing with someone how you might find that information can be even more helpful. One of my mentors, Andrew Fraknoi, talked about such a transition from being a "sage on the stage" to a "guide on the side".

- i. Ask a question
- ii. Learn a story – representation matters
- iii. Show your work

There is so much research on these topics. I will include some links in the accompanying paper. We've also created a series of 5 short videos that share some simple tactics for making astronomy more welcoming. Again, these are aimed at engaging girls, but the processes work well for anyone who doesn't feel like they could be a scientist.

Unless we are more welcoming, the landscape of astronomers and physicists is not going to change. It is up to us to make sure that astronomy is open to everyone. And it's not rocket

science. Thank you so much for spending this time with me. I hope you try one of these and if you do, send me an email and let me know how it went. I'd love to hear how they work for you.

- 5 Tips for Girl-Friendly Astronomy Events
- SciGirls Strategies: How to Engage Girls in STEM
- Tips for Adults Generation STEM: What Girls Say about STEM
- San Francisco Bay Area Rematriation efforts – Give Shuumi

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- [2] The development of children's gender-science stereotypes: A meta-analysis of 5 decades of US Draw-a-Scientist studies DI Miller, KM Nolla, AH Eagly, DH Uttal - Child development, 2018.



GalileoMobile: Lessons Learnt from a Volunteer Outreach Initiative Sharing Astronomy with Communities Across the World

Speaker: Jorge Rivero Gonzales, Institute of Space Sciences (ICE-CSIC), Spain

Collaborators: S. Benítez Herrera (ESA), F. Carrelli (Independent Filmmaker), E. Penteado (IAU OAE), F. del Sordo (ICE-CSIC), D. Torres Machado (Centro Brasileiro de Pesquisas Físicas), F. Frangkoudi (Durham University), A. Paula Germano (Museu de Astronomia e Ciências Afins), N. Gomes (Dalhousie University), P. Kobel (École Polytechnique Fédérale de Lausanne), E. Ntormousi (Scuola Normale Superiore, Pisa), M. Seidel (Caltech / IPAC), P. Figueiró Spinelli (Museu de Astronomia e Ciências Afins) and M. Vasquez (EUMETSAT).

GalileoMobile is a volunteer astronomy outreach initiative that shares astronomy with students and teachers in communities worldwide. Since its inception in 2008, the GalileoMobile initiative - composed of a group of volunteer astronomers, educators, and science communicators around the world - has reached 2,500 teachers and 20,000 students from 15 countries providing different communities with the tools to run astronomical activities independently, facilitating their sustainability through teacher workshops and community building. In this talk, we will give an overview of GalileoMobile's vision, major achievements, challenges, and lessons learned.

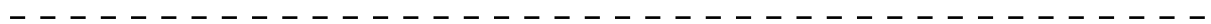




Figure 1: Earth as a peppercorn activity performed as part of GalileoMobile's BraBo project in Brazil in 2014. Credit: GalileoMobile.

GalileoMobile [1] is a volunteer astronomy outreach initiative that shares astronomy with communities around the world. GalileoMobile's vision is to share astronomy across the world in a spirit of inclusion, sustainability, and cultural exchange to create a feeling of unity under the same sky. GalileoMobile is comprised of a multidisciplinary team of astronomers, educators, science communicators, journalists, and film-makers.

GalileoMobile goals are:

- To visit schools and communities and organise astronomy hands-on sustainable activities, sky observations, and donate educational material;
- To provide schools and teachers with the tools and knowledge to run the activities independently, facilitating sustainability through teacher workshops and community building;
- To encourage peace and mutual understanding by acknowledging, alongside modern scientific views, traditional knowledge related to astronomy and the cosmovisions of the communities visited;
- To share the experiences with a wide audience through appropriate channels and resources in order to inspire initiatives with a similar vision.

Originating during the UN International Year of Astronomy 2009 [2], when it was designated IY2009 Special Project, GalileoMobile has organized actions in 15 countries. The project has shared astronomy with more than 17,000 students and 2,000 teachers, with over 1,000 people participating in GalileoMobile public events. Furthermore, it has been recognized as a best practice organization in informal science education by the European Commission [3]. In addition, the scope of the GalileoMobile projects has included activities with underrepresented groups, such as indigenous people in Brazil, communities in territories in conflict, such as the separated Greek and Turkish Cypriot populations in Cyprus or the Sahrawi community, which has one of the most protracted refugee situation in the world, with refugees living in camps near Tindouf, Algeria, since 1975.

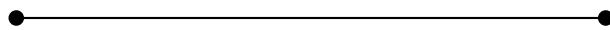
Another important outcome of GalileoMobile actions is the production of audiovisual products to inspire people worldwide to organize similar activities and provide communities with a platform to share their message to the world. At the moment, we have produced several documentaries, a photo-book, and lately we have been experimenting with innovative formats such as podcasts, interactive documentaries, and virtual reality experiences to spread our actions as widely and effectively as possible.

GalileoMobile Handbook of activities

GalileoMobile activities are centered around the GalileoMobile Handbook of Activities [4] which comprises around 20 astronomical activities that we adapted from many different sources, and translated into 6 languages. The Handbook is freely available to download from the Galileo-Mobile website. What the Handbook's activities have in common is that they are interactive and practical, they follow the inquiry-based learning approach, and they are low-cost, utilizing materials that can be found anywhere in the world. The main topics are our planet Earth, the Solar System, and the Milky Way because they are easily observable by the eye and offer concepts that can be treated at a basic level to excite the imagination for other worlds and illustrate the uniqueness and fragility of our own planet.

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- [3] Science Education for Responsible Citizenship (European Commission, 2015).
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Exploring Astronomy Education Through Astrophotography: School Contest Open for Everyone

Speaker: Dragana Ilić, Department of Astronomy, University of Belgrade –
Faculty of Mathematics, Serbia

Collaborators: Marina Pavlović, Mathematica Institute, Serbian Academy of Sciences and Arts & NAEC Serbia & Society of Astronomers of Serbia; Jelena Kovačević Dojčinović, Astronomical Observatory Belgrade, Serbia & NAEC Serbia & Society of Astronomers of Serbia; Milica Vučetić, Department of Astronomy, university of Belgrade - Faculty of Mathematics, Serbia & NAEC Serbia & Society of Astronomers of Serbia; Monika Jurković, Astronomical Observatory Belgrade, Serbia & NAEC Serbia & Society of Astronomers of Serbia; Vladimir Kržalić, Society of Astronomers of Serbia; Tijana Prodanović, Department of Astronomy, university of Belgrade - Faculty of Mathematics, Serbia & NAEC Serbia & Society of Astronomers of Serbia; Miodrag Sekulić, Astronomical Observatory Belgrade, Serbia; Bojan Arbutina, Department of Astronomy, university of Belgrade - Faculty of Mathematics, Serbia & NAEC Serbia & Society of Astronomers of Serbia; Stanislav Milošević, Department of Astronomy, university of Belgrade - Faculty of Mathematics, Serbia & NAEC Serbia & Society of Astronomers of Serbia

In 2023, we ran a first national astrophotography contest, “Take a Photo of the Night Sky,” that was intended for primary and high school pupils from Serbia, whom we invited to submit one photo in teams of no more than five pupils, under the supervision of a teacher. To enable equal participation for every school child we set as a requirement that only a mobile device (phone or tablet) could be used, while we provided an online training for all registered teams on how to make a successful photo of the night sky using a mobile device. We had 184 teams in the competition, including more than 1,400 pupils and 200 teachers from all over the country. In the following, we would like to share our experiences, hoping to promote this format of astrophotography contest as astronomy education that may reach every school child in Serbia.



Talk link: <https://youtu.be/vEoNnh7dV18>

Motivated by the intentions to provide elementary and high-school pupils with astronomy topics and new teaching approaches, aiming to stimulate their interest in natural sciences, particularly astronomy, the National Committee for Astronomy Education within the International Astronomical Union (National Astronomy Education Coordinator (NAEC) team for Serbia, <https://www.astro4edu.org/naec-network/RS/>) organized the first astrophotography contest in Serbia for elementary and high school students, under the umbrella of the Serbian Astronomical Society.

The contest entitled “Take a photo of the Night Sky,” took place from December 2022 to March 2023 and received a significant response from students across the country. Nearly 1,400 students from approximately 400 teams, guided by about 200 teachers, participated in the competition. What makes this competition unique is that the main requirement was that the photographs are taken exclusively with mobile phones or tablets. This approach enabled equal participation for a vast number of children as no expensive equipment was needed to make a professional astrophotography, only some simple training. Thus, to make sure that all participants had the same starting position, we organized a training on how to successfully capture the night sky with average mobile devices. The online training session was provided at the beginning of the contest by our expert collaborator and jury president Vladimir Krzalic. The session recordings were available throughout the whole competition.

Teams composed of 1 to 5 students from the same elementary or high school, together with a teacher/supervisor, were eligible to participate. One teacher could supervise multiple teams, while team members had to be different. Astrophotography involved capturing images of the night sky and celestial objects such as planets, stars, nebulae, and galaxies. To have a photograph accepted as astrophotography, it had to be taken during the night and it had to feature a celestial event, such as the Milky Way, the Moon, a star cluster, a constellation, or just the night sky captured through a long exposure to include star trails. Various types of nightscapes containing elements of astrophotography were also considered. Each team could submit only one astrophotograph. The photographs considered for evaluation had to be taken exclusively with a mobile phone or tablet. Additional equipment such as adapters and stands were allowed. The submitted photograph had to contain an EXIF file containing all information about the photographic process. Instructions on how to obtain this file were provided during the professional training. The minimum resolution of the photograph had to be 3000 pixels on the longer side, and the accepted format was jpeg. Editing photographs in any image processing software was allowed. Along with the final edited photograph, an original unprocessed image had to be submitted. If the final edited photograph was a composite of multiple consecutive shots, only one original unprocessed photograph needed to be selected and submitted.

Around 200 teams submitted successful astrophotographs, which were evaluated by the expert jury composed of Vladimir Krzalic, Miodrag Sekula, Dr. Marina Pavlovic, and Prof. Dr. Tijana Prodanovic. From a highly competitive field, the jury selected the top three works from teams at Pozarevac Gymnasium (first prize), “Sinisa Janic” Elementary School in Vlasotince (second prize), and “Vuk Karadzic” Elementary School in Belgrade (third prize). Additionally, a special award was given to the youngest team, consisting of first-grade students from “Svetozar Markovic” Elementary School in Kragujevac.

The winners were officially announced and the awards were delivered to the most successful teams on April 1, 2023, during the award ceremony at the Astronomical Observatory in Belgrade. The top three teams received valuable prizes in the form of school telescopes, while the top 15 astrophotographs were featured in the special exhibition. All attendees had the opportunity to visit the museum at the Astronomical Observatory and the Great Refractor, one of the largest telescopes in Europe in the first half of the 20th century.

On this occasion, a special exhibition, “Take a picture of the Night Sky,” was opened in the Great Refractor Gallery at the Astronomical Observatory, showcasing the 15 best-placed astrophotographs, allowing a larger audience to become familiar with the most successful works



Figure 1: 1st Place Photography Title: “Star Trails Above the Roofs of Pozarevac on a February Evening”. Authors of the Photography: Boban Jankovic, Bogdan Milakovic, Nikola Milakovic (students, 3rd grade secondary school), Mirjana Zivojinovic (teacher), Pozarevac Gymnasium, Pozarevac.

of elementary and high school students. The exhibition of the best astrophotographs was on display until mid-November 2023 and was visited by a large number of visitors, including officials from the embassies of Russia, China, and USA.

The competition was supported by four major institutions in Serbia with professional astronomers (Astronomical Society of Serbia, Astronomical Observatory Belgrade, Faculty of Mathematics - University of Belgrade, Mathematical Institute of the Serbian Academy of Sciences and Arts), and partners from the private sector, United Cloud and EPSON Serbia, who provided valuable prizes for the winners. For more details visit the dedicated website of the contest <https://sites.google.com/view/uslikajnocnonebo/home>.



Figure 2: 2nd Place. Photography Title: "Starry Sky Above the Memorial Park in Vlasotince". Authors of the Photography: Nina Antic, Jana Gorunovic, Isidora Ilic, Sofija Stojanovic (students, 8th grade elementary school), Tatjana Mihajlovic (teacher), "Sinisa Janic" Elementary school, Vlasotince.



Figure 3: 3rd Place. Photography Title: "Night Sky at the Foot of Mount Dinara in Dalmatia". Authors of the Photography: Filip Bobacev, Mihajlo Petrovic, Ema Radulovic, Dunja Stojkovic, Nina Susic (students, 7th grade elementary school), Marina Lakcevic (teacher), "Vuk Karadzic" Elementary School, Belgrade.



Astronomy for Non-Astronomers

Speaker: Myriam Alqassab, Bahrain Stargazers Astronomy Club, Bahrain

Key points

- Why teach astronomy to students?
- How can an astronomy club contribute to astronomy education?

One of the fascinating subjects that students can enjoy learning about is astronomy. It is a science that combines many subjects, including physics, mathematics, geology, history, applied sciences, mythology, and many more. Astronomers play significant roles in astronomy education as academics at universities and beyond that. However, astronomy is not limited only to academics; everyone has the right to engage and participate in this beautiful science. This leads us to the role of education and outreach through schools, teachers, amateur astronomers, and astronomy clubs. An example of this is the Bahrain Stargazers Astronomy Club.



Talk link: <https://youtu.be/bnYNbDYj4pE>

Contribution of the Bahrain Stargazers Astronomy Club to astronomy education at the school level:

Bahrain Stargazers is a non-profit organization founded in November 2016 with around 150 members of various nationalities. The club aims to educate and raise awareness through astronomy outreach activities to grow a community of future astronomers and astronomy enthusiasts.

In 2019, the club started the Astronomy for Non-Astronomers program to teach astronomy to students during after-school activities. The goal of the program is to teach students astronomy and motivate them to engage in and participate in astronomy workshops, campaigns, competitions, and citizen science. It also aims to develop students' curiosity in astronomy so they can pursue astronomy as a career.

Why teach astronomy to students?

- To prepare future generations of professional astronomers who will venture into the unknown.
- Astronomy can help students improve their communication skills.
- Astronomy can stimulate students' minds.
- Astronomy is a gateway to other sciences.
- Students can find inspiration in astronomy.
- Astronomy can improve students' computer literacy.

How can an astronomy club contribute to teaching astronomy?

- Astronomy clubs are excellent ways to keep kids occupied with learning.

- Joining an astronomy club allows students to meet other enthusiasts to work with and learn from.
- Through astronomy clubs, students can meet professional astronomers and astronauts.
- Through the ongoing activities, students can get involved and participate in astronomy-related citizen sciences.
- Astronomy clubs give students a glimpse of professional astronomy.

Below are some of the activities included in the Astronomy for Non-Astronomers program:

- **After-school stargazing sessions and astronomy parties:** to learn about the night sky, observation, and light pollution.
- **The International Astronomical Search Collaboration (IASC):** to learn about observation, astrometry, asteroid discoveries, and the Naming of Astronomical Objects.
- **The Stargazers Summer Camp:** is an online, 5-day-long camp that includes a variety of astronomy-related activities and is open to everyone aged 6 to 12 during the summer holiday.
- **Art and the cosmic:** through this activity, we bring art and astronomy together to make sure that astronomy serves as a motivating factor for hobbies.
- **Earth from the above:** this activity teaches students about remote sensing, how to analyze data, take measurements, and process images taken by satellite using Landviewer.
- **Astro imaging analysis activity:** teaches students about photometry, spectroscopy, remote telescopes, archives, and spectra.

As a result of the club's efforts in astronomy for education and outreach, the public and schools are expressing a strong interest in enrolling in this program for science-related after-school activities, summer camp activities, and STEM workshops for their students to enjoy astronomy activities with a glimpse of professionalism.

In the Kingdom of Bahrain, the Bahrain Stargazers Club is the only active institute that provides astronomical activities to the public, and we hope this initiative will attract more institutions and centers towards astronomy education.



Astronomy Outreach and Mobile Libraries. Bringing Science to New Audience and New Audience to Books

Speaker: Cuauhtemoc Mendez, Professor of Physics and Astronomy at Tec de Monterrey campus Guadalajara. Content director at TRIBU cultura astronómica, Mexico

Collaborators: Kathya Franco Ramos, Bibliotecas de Zapopan; Rafael Zepeda Zepeda, COECYT-JAL

During the last edition of Festival de la Astronomía TRIBU, some Astronomy experiences were accompanied by a mobile library. We present quantitative and qualitative results, analyzing the importance of reaching new places to capture new audiences and using a simple and friendly approach with non-experts in science. Towards the end, we share feedback from the public on the aspects that most caught their attention. We found that bringing new experiences to new places, especially in rural areas, captivates the interests of a lot of people because these experiences are not common in Mexico and because stargazing is naturally attractive among people.



Talk link: <https://youtu.be/J0fFyxJuiHI>

Mexico does not have important centers dedicated to promoting reading; commonly, the only place where young people have access to books is at school. Generally, these do not have materials that attract the public's attention. In addition to the above, school dropouts occur mainly at the secondary school level — mostly, due to economic reasons. The most unfortunate thing is that these young people become adults who will no longer read books nor will they have options to continue their education. In this talk, I will share some experiences and results that we had when we combined mobile libraries with the dissemination of Astronomy, both in the metropolitan and rural areas of the state of Jalisco.

TRIBU cultura astronómica (TRIBE astronomical culture) is the name of our NGO. The team comprises four teachers from different topics such as Astronomy, Physics, Social Development, and even clownery and juggling. The most important part of the team is a crew consisting of seven young people who were formerly students of physics or astronomy teachers. The NGO is based in Guadalajara, capital city of Jalisco, Mexico.

Paradoxically, Guadalajara is the venue of the biggest Spanish-speaking International Book Fair, which is also the second biggest book fair in the world. However, this has not contributed to



Figure 1: Bruno the Pirate teaches children how they oriented themselves with the stars to navigate.



Figure 2: The mobile library ready to welcome new audiences.

improving reading levels in Jalisco. Due to Mexico's economic situation, a large number of children are pressured to abandon their secondary school education, leaving their educational journey.

On the other hand, Astronomy is a topic that naturally attracts people and awakens a natural curiosity. The opportunity to use a telescope in itself attracts audiences to gather around it. The latter is something that we noticed on the astronomical nights that we do regularly, both in urban and rural areas of Jalisco.

Considering the above, we decided to join efforts with two government agencies that share a common interest with our organization: the first is COECYTJAL, Council for Science and Technology in the state of Jalisco, which has the Mobile Science Library program that has activities in most municipalities of Jalisco. The second is the "Luciérnaga" project, led by the Municipality of Zapopan, in the second most important city of Jalisco. They established an innovative mobile library aimed at reaching children residing in the most vulnerable areas of the city.

Together, we designed Astronomy outreach experiences that included thematic talks, interactive activities, and observation with telescopes. The initiative resulted in attracting new audiences to the library, who became familiar with the books and activities that happen in these places.

The standard sequence of the experience unfolds as follows: 1) installation of all physical equipment (the mobile library, stage, screen, and telescopes). 2) educational circus show. Bruno the Pirate (a professional clown and juggler characterized as a pirate) begins to juggle to capture the children's attention and invite them to participate. 3) Screening of a video by Bruno about the astronomical topic chosen for that date. 4) Bruno deepens the explanation in an interactive



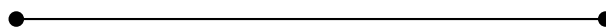
Figure 3: Telescopes prepared for observation when night comes.

way with the participation of the children. 5) Invitation to observe the stars that Bruno told them about in the telescopes. 6) Invitation to enter the Mobile Library to listen to a story, read with their family, or draw activity sheets. This series of activities was repeated two or three times throughout the night so that the people who were passing by could join in the experience.

When the experience was set up in rural areas, it had to be adapted to accommodate more people. In this scenario, the mobile library placed tables outside in order to showcase the interactive elements such as planet spheres, asteroid rocks, infographics, and even an orrery, allowing the public to interact with them. Activities were also organized for the participants. At the same time, the observation with telescopes took place and a large screen entertained the audience with Bruno's videos. Also, something quite important happened, local residents were invited to come and sell food and drinks. All these together made the experience more pleasant and encouraged people to stay longer. In addition, an economic benefit for the community was generated.

We, as teachers, are very interested in the curiosity with which people, both children and adults, approach learning about Astronomy, space science, planets, and stars. However, we also realize that even more important than the possible educational impact we can achieve is the social impact on people. Making them feel that although they may be outside the school system, knowledge is something both interesting and within their reach. The most important thing we can achieve is to remind them that we are all part of the same tribe.

These activities were made possible thanks to a call from COECYTJAL for the dissemination of sciences, providing the economic resources to develop these experiences.



Astronomy for Equity, Providing Opportunities in STEM to the Unserved Through Astronomy

Speaker: Mike Simmons, Astronomy for Equity, USA

Astronomy for Equity is a new initiative under the NGO Blue Marble Space that uses astronomy to provide opportunities for marginalized communities through astronomy. A remote observing program, offering research-type project experiences, has recently commenced with students at a university in Benghazi and students of an astronomy club in Afghanistan. Students in schools in Ukraine will soon be involved. While this project may be considered informal education, it is augmenting the formal education programs of students who would not otherwise have the experience of a research-type project. Resources for teaching astronomy to the blind and visually impaired, along with experienced practitioners, are being brought together with astronomy clubs worldwide to train hundreds, if not thousands, of outreach amateur astronomers to include this community in their ongoing activities. Telescopes have been acquired through crowdfunding for astronomy clubs in five cities in Libya that have the support of a Libyan astronomy NGO and the Education Ministry but couldn't acquire telescopes by themselves. Telescopes are en route to astronomy students in Ukraine. Fundraising through the sale of eclipse glasses for the annular eclipse in the US in 2023 will also include the sales of glasses purchased for donation to STEM students at schools in indigenous communities. This program will be extended to more schools for the 2024 total eclipse. Additional programs are in development, utilizing existing resources to address problems such as resource underutilization, lack of expertise across community borders, and even lack of awareness of potential pathways to STEM careers. These conditions are unfortunately common for most of the world's potential STEM students. There are young people everywhere with the ability to shine and make a difference in their communities and in many STEM fields who just never get the chance. These communities are the unserved, beyond the reach of NGOs providing services for underserved communities. Due to a lack of even the most basic opportunities, these talents go to waste. Local solutions are needed to build local infrastructure, starting with human capacity, not only to provide STEM education but to create an environment where people value such education and all students can participate.



Talk link: <https://youtu.be/ikqU8Y0QD4g>

There are young people everywhere with the ability to shine and make a difference in STEM and in their communities who just never get the chance. For lack of even the most basic opportunities, these talents go to waste. Local solutions are needed to build local infrastructure, starting with human capacity, to not only provide STEM education but to create an environment where education is valued and all students can take part.

Astronomy for Equity (A4E) is a new initiative within Blue Marble Space that uses astronomy to provide opportunities for marginalized communities through astronomy. While many organizations target the underserved, A4E addresses the needs of the “unserved” who are beyond the purview and networks of most NGOs. This describes the vast majority of students worldwide who don’t have access programs to opportunities like many underserved communities do in developed countries. For the most part, they’re unlikely to even learn of support services in their area. They are effectively invisible to most programs. Those with physical or other challenges sit on the sidelines of programs even in advanced countries. These students lack educational opportunities that are taken for granted by others. Astronomy is used in many ways to provide STEM students and teachers with hands-on experience. Telescopes and training provide access to the natural laboratory everyone has access to. For example, Mount Meru Astronomical Observatory (MMAO) (an offshoot of an earlier program, Telescopes to Tanzania) is a training facility for students and teachers in northern Tanzania. With rural skies and an adjacent wildlife reserve, the observatory’s sustainability plans include astrotourism programs and A4E-operated astrotourism/wildlife tours. It is hoped that this facility will become a template for others in Africa and elsewhere.

Few students will have an educational observatory like this within reach but remote observing would enable them to gain practical experience in astronomy and introduce them to research in general. With the help of other Global Sky Partners of Las Cumbres Observatory (LCO), A4E conducted a pilot program during the summer of 2023. The program involved students in an astronomy club at a university in Benghazi, Libya, as well as the two leaders of the Kayhana Astronomical Group in Herat, Afghanistan. Students made photometric measurements of the supernova in M101 using LCO’s research telescopes and produced a light curve, thereby learning the principles behind astronomical observing and research methods applicable to all fields. Although the students were mostly engineering students with a passion for astronomy, the hands-on experience with the advanced technology of LCO’s research telescopes, data collection, and interpretation of the results will benefit them in whatever field they end up in.

The next remote observing program will include students from AstroSandbox, an astronomy education organization in Ukraine. AstroSandbox provides online classes and also trains students for international astronomy competitions. The war in Ukraine has interrupted the studies of countless students whose future has become uncertain. Many are internally displaced and all are subject to psychological stress. The new opportunities will benefit these young people in many ways besides the learning experience.

A4E has provided support for other astronomy students in Ukraine as well. Students in three cities, where infrastructure is continuously bombarded and power outages are common, found a silver lining as the skies darkened, providing them with an unfettered view of the night sky. They requested telescopes through another program that was passed on to A4E. Three crowdfunded

telescopes have been provided so far, all small and easily portable to allow for quick retreats to bomb shelters. A4E's founder will lead a small group to Ukraine to visit the students, including a documentary filmmaker who will tell the students stories of how the night sky provides some solace and a chance to dream during a very difficult time.

Telescopes have also been crowdfunded and sent to middle school astronomy clubs in five cities in Libya, created by Roaya, a Libyan astronomy NGO, with support from the Education Ministry. Roaya is very active and has run many programs for the clubs but they couldn't acquire telescopes for them. A group visit to Libya for the planned first national astronomy festival was cancelled after the recent flooding disaster that swept away much of the city of Derna and caused extensive damage elsewhere. This is just the latest setback for young people growing up in Libya after the civil war, ISIS, and unrest but A4E will continue to support Roaya's efforts as they reach for the stars.

Others lack access to programs due to physical issues. People who are blind or have low vision are also as curious about the cosmos as anyone else but the visual ways in which astronomy is presented make it largely inaccessible to them. While astronomy began as a visual pursuit, it now encompasses almost all wavelengths, yet representations are still primarily visual. Astronomy resources for those without vision are plentiful and there are many experts proficient in their use, but the field is virtually unknown to the majority of educators and outreach astronomers. A4E has created a group where these resources and experienced practitioners are brought together with astronomy clubs worldwide interested in learning how to include this traditionally excluded group in their outreach programs. Among the trainers are amateur astronomy clubs who lead by example and encourage others to get started. New practitioners will in turn train more, leading to hundreds, if not thousands, of outreach amateur astronomers who will include this community in their ongoing activities as the knowledge spreads. The group is open and can be joined at groups.io/g/A4E-BLV-outreach.

A4E fundraising includes sales of A4E-branded eclipse glasses for the total solar eclipse that crosses the US on April 8. Customers are also being offered the opportunity to purchase eclipse glasses for donation to schools that qualify for federal assistance and schools in native American reservations. A previous campaign in 2017 provided 100,000 eclipse glasses for schools across the US including donated glasses from other organizations and manufacturers.

The lack of opportunities is rarely caused by a lack of resources; rather it is caused by a lack of access, which encompasses awareness, utilization, and distribution. Abundant resources, including expert teachers, don't reach the unserved. Through the universal interest and accessibility of astronomy, Astronomy for Equity utilizes the volunteer astronomy community worldwide, bringing together experts, learners, and existing resources to address the lack of access for STEM students. Those in the field are empowered through the sharing of existing resources and knowledge. A little can go a very long way with people motivated to help the unserved through astronomy.

POSTER CONTRIBUTIONS

Park of Sunclocks in Horodnic de Jos - Romania

Presenter: Elisabeta Naghi, National Education Ministry, Romania

In Horodnic de Jos (Romania) we can visit the Private Popular Planetarium since 2006. From 2023, we can find an open-air park with sundials of various types in the planetarium: vertical, vertical with two sides (it shows the hours between 6 am and 6 pm on the southern face and on the northern face it can show the hours between 4-6 am and 6-8 pm in the summer), horizontal, equatorial and one human. In this place, the public — the local community, domestic tourists and tourists from abroad — comes to learn to build sundials and to visit the table of time, which shows us the role of the Egyptian obelisk, the origin of the names of the days of the week and the zodiac signs. Visitors can also learn here about the Earth movements, hours, time zones and the equation of time.



Poster link: <https://doi.org/10.5281/zenodo.10445195>

Our poster includes, in the following order: different types of sundials, sundial built by students, table of time, teaching materials used for practical demonstrations and constructions, and planetarium visitors - children and adults alike.

Many types of sundials are well known and in the Horodnic de Jos Planetarium, we can find some of them. Each figure in the first image of the poster corresponds to a sundial as follows: 1-human clock, 2-vertical two-faced clock, 3-horizontal sundial. 4- vertical sundial made from a TV antenna, which represents both the hours in Romanian Legal Time and the delay of 17 minutes due to the passage of the Sun at the meridian of Horodnic de Jos. 5- vertical sundial on the southern facade of the Planetarium building, 7- two equatorial clocks, one in the form of a disc with two faces and one in the form of a semicircular band, 8- horizontal clock in the form of a flyer whose antennae indicate the hours, placed on a huge mushroom made from a TV antenna), 9 - panel with images of teaching materials used for demonstrations and practical constructions, and 6 - the table of time.

At the I.G. Sbiera Secondary School in Horodnic de Jos, built in 1911, there was a sundial that worked for about 90 years. The shadow of the gnomon was cast onto the window where the teachers were sitting so that they could find out the time from inside the building. In 2003, by replacing the classic windows with insulating glass, the clock was destroyed due to negligence. In 2017, the initiative to build a new sundial was taken under the guidance of a teacher Olenici Dimitrie. Together with a group of students — as a part of the project called Hora Fugit — they



made a new sundial that still exists today in the schoolyard.

In the courtyard of the Planetarium we find the Table of Time, which is a construction in the shape of a horizontal sundial that illustrates the role of the Egyptian obelisk in dividing the day into two equal parts.

It is displayed alongside a meridian, which illustrates the lengths of days and nights in each month of the year. The construction is made out of a 120-year-old fir trunk. The signs of the seven ancient planets, from which the names of the days of the week originate, are placed on and around it. Next to the seven symbols of the planets, seven scales can be found in the form of petals. The 12 chairs built from fir trunks, which are marked with the 12 zodiac signs, are placed around the table. On the central table, there are three images of the Egyptian sphinx, the pyramid of Cheops, and the image of the three gods who make up the universe in old Egyptian belief: ZeB-the god of the Earth, the god of air Shu and the goddess Nut of the sky.

The didactic materials used for demonstrations and practical constructions can be seen on a panel in the planetarium courtyard. They give us information about the time and the sundials. The elements necessary for their construction are the positions of the Earth at equinoxes and at solstices, the equation of time, etc.

Just like any planetarium, the Planetarium/Astronomical Observatory and the sundial park are often visited by organized groups of preschoolers, students, Romanian tourists, tourists from other countries, official delegations, etc. We recollect that some of the visitors were also jury members of the observational test of the International Olympiad of Astronomy and Astrophysics (IOAA 2014), organized in Suceava, a group of Romanian students participating in the Olympiad of Astronomy and Astrophysics in Poland in 2023, a group of Korean students, a group of mayors from France,...

Students from nearby schools and the countryside visit the planetarium during extracurricular activities.

During the visit, there are practical demonstrations of sundial construction and visitors can learn basic concepts for building sundials.

The various types of sundials here were also presented in the local media and in a calendar entitled Timpul Soarelui - made by the specialist in gnomonics Dan George Uza from Cluj-Napoca.

We are waiting for you to visit us!



Home Astronomy for Early Childhood and its Assessment

Presenter: Akihiko Tomita, Wakayama University, Japan

Collaborators: Takuya Kotani, Osaka Ohtani University, Japan; Yoshiko Nagase, Osaka Ohtani University, Japan; Yukiko Takegawa, Science Planning Office for Kids, Japan; Hiromi Tsuji, Osaka Shoin Women's University, Japan (KSRUG, Kansai Scientific Research Union Group for early childhood science education, Osaka, Japan)

Young children interact with their surroundings, things, objects, and nature, and by “trying one more time”, they enjoy observing and building concepts. This is also the case for the subject of astronomy. We present records of interests and behaviors of 3 to 5-year-old children regarding the evening sky, clouds, colors, rainbows, the first stars, and the movement of the stars. In addition, we present our study of the assessment methods used. We also discuss how such assessment operates within early childhood science education in general and how it relates to science within formal school education.



Poster link: <https://doi.org/10.5281/zenodo.10445208>

Introduction

Is science something very unusual, done by special people, in special places, and in special ways? Of course not — science is for all people. However, there is a problem. Though teachers of nurseries, kindergartens, or pre-schools like to enjoy science with early childhood students, the teachers have less confidence when it comes to the practice of science activities. A possible solution to the problem is to introduce playing with science in everyday life, such as through home astronomy. This would be more effective in early childhood, since teachers are good at this kind of practice. However, evaluation is not easy, which might make the teachers hesitate to step into the science activity. This research will focus on the practical examples and evaluation methods discussed in KSRUG, a research group for children's scientific play that focuses on children's involvement in objects, and phenomena, especially natural phenomena, with particular emphasis on the pre-school to early elementary school years.

Materials and methods

Not only implementing fun activities but also recording and evaluating them are important and necessary steps to improve the practice. At the Universe Awareness program, based at Leiden University in the Netherlands, they developed a useful evaluation guide complementing their slogan “inspiring every child with our wonderful cosmos.” [1]. By using the evaluation guide as a reference and observing various practices at nurseries, kindergartens, and preschools, we

established evaluation points for pre-primary education to early grades of primary education, as summarized below. Not all of these aspects are commonly observed in home astronomy activities. Enjoyment, inspiration, curiosity, observation, and trying to interpret are the ones most frequently observed.

1. Motivation

Enjoyment / Inspiration / Curiosity

2. Skills

Observation / Asking / Exchanging Opinions / Interpreting (Trying to Interpret, Explain)

Trying / Devising / Confirming / Recording (by drawing) / Preserving

3. Attitude

Leading to various creative activities / Understanding and admiring other's opinions

We introduce an example of the record and evaluation in the next section, using an article titled "Evening Sky Watching for Students", published in AstroEdu, an online peer-reviewed practice repository [2]. The practice is presented in the form of conversations between a child (C) and a parent or a nursery teacher (T). The conversations are a combination of several actual practice records, edited and reproduced. After reviewing the record, we aimed to establish evaluation points from those listed above.

Examples

Theme: A star's motion

T: Do stars set?

C: No! Stars float.

T: Does the Sun set?

C: Yes. Evaluation: skills - observation

T: Why do you think so?

C: I saw it. Evaluation: skills - interpretation

T: Then, does the Moon set?

C: Yes. I saw it.

T: Then, why do you think stars don't set?

C: I didn't see it. Stars pop up and float in the night. Evaluation: skills - opinion

Motivation: enjoyment / curiosity

Children answer yes or no based on what they see in their daily life. It is a scientific attitude. With solid experience, they will surely say: stars set and stars move — because they saw it.

Theme: The motion of the clouds

T: Are the clouds moving?

C: The clouds are floating. Evaluation: skills - observation

T: Look at the clouds for a while.

C: The clouds are moving! Their shapes are changing! Motivation-Inspiration

Motivation: enjoyment / curiosity

Some children often draw stereotypical clouds as pretty cotton on the upper part of the sheet. Rather than simply telling them that clouds are not still, one can encourage them to notice it.

Theme: Stars or airplanes?

T: How do you tell stars apart from airplanes or helicopters?

C: Stars shine steadily. Airplanes shine on and off. / Stars don't move. Airplanes do.

C: The color is different. Stars are not so colorful. / Stars do not make a sound.

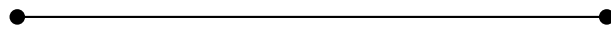
Evaluation: skills – observation / interpretation / opinion

Motivation: enjoyment / curiosity

Based on what they see in their daily lives, children can distinguish stars from other objects. It is important to allow them to explain the reasons behind their observations. They will try to explain using words or gestures.

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- [2] “Evening Sky watching for students” Tomita (2016) AstroEdu <https://astroedu.iau.org/en/activities/evening-sky-watching-for-students/>



Astronomy on TikTok

Presenter: Tijana Prodanovic, Department of Astronomy, Faculty of Mathematics, University of Belgrade, Serbia

Besides being a researcher in the field of astrophysics for 20 years, I have also been a science communicator for 15 years. It is my feeling that in that time, none of my efforts, and those include organizing science festivals and Researchers’ Nights attended by 25 thousand visitors, have resulted in such an impact as my TikTok educational astronomy profile (Dr Cosmic Ray) has. In this talk, I will present some main benefits and potential that TikTok and similar platforms have for astronomy education in digital space.



Poster link: <https://doi.org/10.5281/zenodo.10445257>

In this poster, I share a short presentation of my experience in astronomy education and popularization using TikTok platform, under profile @drcosmicray.

I started creating content on TikTok in September of 2021 as a part of the European project Researchers' Night that we were organizing that year, with one of the main themes being science in digital space. Even though I have been actively doing science communication since 2008, I had very little experience in communicating science online or on social networks. I wanted to create a YouTube channel on multiple occasions, but the level of editing, montage, and technical preparation was always the major obstacle as I couldn't find enough time to do that next to being a full-time University professor and a part-time science communication officer.

The first TikTok video I posted had more than 10k views. The number of views and followers kept increasing in the following days. Currently, I have 55k followers, even though I do not create content regularly.

Based on my experience as an educator here are my main benefits of TikTok over other platforms:

- 1) TikTok is now the dominant platform used by those younger than 18 (Gen Z and Alpha). It is thus perfect for education outside the classroom.

- 2) The culture of consuming content on TikTok is such that people dominantly watch what the algorithm suggests and not content from whom they follow. Furthermore, a significant fraction of content pushed to users is random and not based on their preferences alone, thus ensuring that even people who are not your target audience, and more importantly vice versa, will be exposed to your content. For example, I get a lot of comments from people who said they did not like physics but liked my content. This suggests that they probably do not actively seek physics, astronomy, and science content in general, but when they are exposed to it, they realize that they like it.

- 3) People prefer authentic content with little or no editing. This is very important for people who do science communication alone and don't have time for any major editing and montage.

- 4) There is a lot of interaction in the comment sections. Children ask lots of questions, many of which are very good. They also engage in peer learning – when I don't answer questions in comments, someone jumps in and answers them.

- 5) Live sessions are like large classrooms. I have hosted many live sessions and there I am usually bombarded with a variety of astronomy, physics, and general science questions.

- 6) When there is a questionable science-related TikTok video by a different profile, people often bring my attention to that video by tagging me, which I then use to respond with a “stitch video”. This is great for debunking fake news and pseudo-science.

While I record videos on different astronomy topics, I have also created a 3 thematic series that have been very well received:

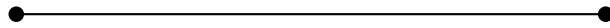
- 1) Alien Detectives: In these videos, I take an alien character from pop culture (from a movie, series, or similar) and discuss how the home planet of this alien could possibly look like. Here, I am trying to connect some properties of living creatures (from biology) with knowledge about planets and exoplanets.

- 2) What If: In these videos, I discuss hypothetical scenarios (e.g. how would life on Earth be different if there was no Moon) that are often based on questions that people ask in the comments. These are a great exercise for connecting various topics and scientific concepts.

- 3) Movie Science; In these videos, I discuss the good and bad science of popular Sci-Fi movies.

In conclusion, short video formats are now becoming the preferred medium for consuming entry-level science. They are more challenging to create than longer formats because of the experience and knowledge of the topic one needs to have in order to condense complex topics

into a few minutes. However, they are excellent for teaching specific concepts. One main drawback is that there is a lot of “fake Moon landing” and “flat Earth” conspiracy videos and theorists who often troll any videos related to the Moon or the shape of the Earth. However, this also presents an opportunity to address these comments with counter videos, which is also something I do from time to time.



Exploring the Cosmos: Enriching Astronomy Education Beyond the Classroom

Presenter: Abhi Raj, University of Delhi, India

This study explores creative astronomy education methods, such as virtual observatories, citizen science initiatives, mobile planetariums, and interactive internet platforms, to enhance learning experiences outside traditional classroom settings. The research examines the impact of these techniques on students' conceptual knowledge, excitement for astronomy, and scientific inquiry abilities. The study also examines obstacles and advantages, such as accessibility, teacher training, and assessment. Adopting these techniques can foster a deeper appreciation for the universe, critical thinking abilities, and a lifetime enthusiasm for science.



Poster link: <https://doi.org/10.5281/zenodo.10445183>

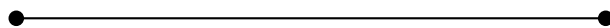
This study explores innovative methods for enhancing astronomy education beyond traditional classroom settings, focusing on non-traditional methods like virtual observatories, citizen science initiatives, mobile planetariums, and interactive internet platforms. The research examines their impact on students' conceptual knowledge, scientific inquiry abilities, and enthusiasm for astronomy. The study highlights the potential of these creative approaches to develop the next generation of scientifically literate individuals. Students are enthralled and curious by astronomy, the study of celestial bodies, and the enormous cosmos. Engaging in astronomy education outside of the conventional classroom setting is a dynamic activity that fosters a deep appreciation for the wonders of the cosmos.

Teachers have the ability to create a cosmic curriculum that goes beyond textbooks in order to properly engage pupils. There are concrete links to astronomical phenomena when lesson plans

incorporate live astronomical occurrences such as planetary alignments, eclipses, and meteor showers. Students can have direct access to the marvels of the night sky through partnerships with observatories and the use of internet resources like virtual telescopes. Immersion in virtual and augmented reality technologies allows students to explore the cosmos in simulated environments, bringing abstract concepts to life and fostering a deeper understanding of astronomy through virtual planetariums and interactive 3D models. Astronomy, a multidisciplinary field involving physics, mathematics, chemistry, and computer science, helps educators contextualize astronomical principles within broader scientific frameworks, enhancing students' understanding of celestial bodies and orbital mechanics. Teachers can also encourage the formation of student astronomy clubs where enthusiasts can collaborate, share experiences, and organize events. These clubs provide a supportive community for students passionate about astronomy and create an environment conducive to learning.

Once we follow the techniques mentioned above, we can introduce several changes in the vision and attitude towards learning science and cosmology. Research indicates that hands-on experiences like observation nights and virtual reality simulations can boost students' interest in astronomy. Active learning methods like citizen science projects and interactive apps improve knowledge retention. Participation in astronomy clubs fosters critical thinking and problem-solving skills. Guest lectures, workshops, and field trips increase interest in STEM careers. Combining quantitative and qualitative data provides a comprehensive understanding of the impact of educational techniques.

While incorporating innovative techniques to enhance astronomy education can be highly beneficial, there are challenges that educators and institutions may face. Schools often lack resources for immersive astronomy education, such as telescopes, virtual reality equipment, and advanced software. Teachers may not be adequately trained to implement these methods, and time constraints can hinder their ability to incorporate additional activities. To sustain interest and momentum, a collaborative effort from educators, administrators, and the community is needed to create a supportive environment for innovative astronomy education. Teaching students about astronomy is crucial due to its ability to stimulate an innate curiosity about the universe, the practical application of scientific principles, and the exploration of celestial bodies and galaxies. It fosters critical thinking and problem-solving skills, teaches complex problems, and provides insights into the historical and cultural significance of celestial observations. Astronomy has played a significant role in human culture and societies.



Students' International Network for Astronomy and its Projects for Sustainable Development

Presenter: Mahdi Rokni, Manager of Students' International Network for Astronomy (SINA), Iran

Collaborators: Akihiko Tomita and Saba Izadi from Commission C1 WG Astronomy Education Research & Methods members; Melika Gonbadi

This network was established by students in a small city in the south of Iran with the aim of globalizing all the activities and plans that they have been carrying out at the Mehr observatory. Some of these activities involve various social skills and different methods for students to use. The main aims of this network are to involve students in astronomical programs and projects, establish a reliable structure for students around the world to meet each other using astronomy as a link, use the methods of sustainable development to teach students about global environmental concerns and world peace, and enable students to make friends with each other without limitation while introducing their own culture to others.



Poster link: <https://doi.org/10.5281/zenodo.10445217>

Introduction

Students' International Network for Astronomy (SINA) regularly organizes activities around the world with students from different regions in order to build up a huge communication network of students based on culture, education, social skills, and all aspects related to astronomy. These activities were officially set in motion by students of Bushehr, a city in the south of Iran. So far, thousands of students around the world have directly participated in SINA's activities. SINA has already been a part of IAU and other international astronomy associations.

Our main aim has been to establish a community based on friendship and international peaceful relations within astronomy, providing various opportunities for students to engage. Even though SINA has mainly been active in Iran, during the last three years, students from different countries such as Japan, Romania, Bulgaria, Spain, and many others from the region were involved in SINA. One of the most important activities of SINA is Astronomy Day in School (ADIS), which includes international Persian ceremonies that have been organized in Iran since 2019. Our future goal is to make an official society in cooperation with IAU and try to include more activities in order to encourage students to join this network.

Main aims of SINA:

- Involving students in astronomical programs and projects

- Preparing a reliable structure for students around the world to meet each other using astronomy as a link
- Using the methods of sustainable development to teach students about global environmental concerns and world peace
- Letting students make friends with each other without limitation and introducing their own culture, activities, and feelings to each other
- Using astronomy and other activities to help them learn social skills such as teamwork, event planning and management, cooperation, and formal behavior

Present and the future of SINA:

- Establish the formal constitution and curriculum for SINA with a Working-Group
- Introduce the network to the world by planning new events and projects
- Accept new students as legal members and support their projects
- Prepare a platform for registration and access to information
- Cooperate with other associations and international projects
- Focus on the new international projects for students in the era of culture, education, astro-tourism, and sustainable development
- Build a strong community with other international projects and organizations such as ADiS, IAU, NARIT, and etc.

Night Sky Photography and Light pollution

Seeing a dark sky and observing the clean sky at night became something very hard to do especially in cities. One of the methods to encourage students and people to focus more on the importance of the dark sky and the dangers of light pollution is to look up at the sky during the night and capture it in order to understand the true situation that our planet is facing right now. Students' International Network for Astronomy (SINA) with Astronomy Day in School (AdiS) and 21st Version of the Silk Road project have been organizing this project as the theme of the International September Equinox meeting of 2023.

Goals

- Encouraging students to observe the sky
- Using cameras and mobiles for a scientific project
- Understanding the methods of sky photography
- Understanding the methods of sky observation
- Involving students in the creation of a light pollution map

Sky Explorers Festival

The "Sky Explorers" festival, is one of the projects created by Students' International Network for Astronomy (SINA) and Iranian Teachers Astronomy Union (ITAU). This festival, first carried out in Mehr Observatory of Bushehr, provides a platform for students to familiarize themselves with the world around and above them in the most realistic way possible. It offers an experience of a life time.

This festival, which is a combination of astronomy and nature, started in march 2013 with the aim of strengthening the spirit of exploration in line with students' self-confidence regarding their abilities. One of the best aspects of this project is that all sections are led by students themselves, whereas teachers have the role of supervisors. Therefore, students become familiar with teamwork and cooperation, respect for others, scientific work on a scientific platform, and last but not least, the responsibility of preparing their own food and other necessities. In recent years, more than 10000 Iranian students from primary school to the second secondary schools

have participated in this event as teams. It is hoped that this number will continue to grow worldwide.

Conclusion

We certainly believe that this festival could become one of the most important and effective activities for students worldwide. We hope this festival will be supported by IAU and other organizations such as UNESCO. We hope to find more cooperation in other countries as well. We have been making efforts to follow the methods and codes of the IAU and UNESCO's strategy plans, especially in the context of sustainable development.

Furthermore, we have received really good support from our colleagues at IAU and also from the co-chairs of the Astronomy Day in School project (ADIS) and the 21st Century Maritime Silk Road. The main organizer of this project is the Students' International Network for Astronomy (SINA).



Exploring the Secrets of the Cosmos on Foot: Astronomy Clubs and Peripatetism

Presenter: José Antonio D'Santiago García, Rafael María Baralt National Experimental University, Mene Grande, Venezuela

Today in the traditional educational environment, the teaching of astronomy is often limited to the confines of the classroom and is based on textbooks and theoretical explanations. This methodology can seem abstract and distant for students, who cannot directly experience celestial phenomena and their connection to the universe. However, the world of astronomy is changing. The astronomy and peripatetic clubs — latter following an educational philosophy that proposes learning outside the classroom and in open spaces, using everything that surrounds us as we walk as the main resource for teaching — have emerged as vehicles for teaching astronomy beyond the classroom, bringing it closer to tangible reality.



Poster link: <https://doi.org/10.5281/zenodo.10445237>

Throughout history, astronomy has been an object of admiration and fascination for humanity. The observation of the stars and the understanding of the secrets of the cosmos have driven human beings to explore and expand the boundaries of their knowledge. However, in the

traditional educational environment, the teaching of astronomy is often confined to the classroom, relying on textbooks and theoretical explanations. This methodology can appear abstract and distant to students, who are unable to directly experience celestial phenomena and their connection to the universe. But what if we could take the teaching of astronomy beyond physical limits and embark on an extraordinary journey through the universe on foot? In this summary, we will explore an innovative way to learn astronomy: astronomy clubs and peripateticism. These two pedagogical techniques have the potential to revolutionize the teaching of astronomy by taking it out of the conventional classroom setting and into the outdoors, allowing young people to explore the secrets of the cosmos interactively and in a participatory manner.

Based on this methodology, we founded an astronomy club for the first time in our city's history, which spans more than one hundred years. It has become an exciting and novel learning space in the field of astronomy. Using an innovative methodology known as peripateticism, we have succeeded in transforming the teaching of this fascinating science and made it accessible to our members, who include students of the university I work for, fellow professors, young people from the community, and some other children.

Peripateticism, inspired by the teachings of ancient Greek philosophers, advocates learning while walking and utilizing everything around us, including our skies, as educational resources. This has allowed us to take the learning of astronomy beyond the classroom walls, immersing ourselves in the vastness of the universe through hikes and explorations into the nature. Instead of limiting ourselves to mere theoretical presentations, we have adopted an active and experiential approach to engage our participants in the process of discovering and understanding the secrets of the cosmos. I have called this strategy, Astronomical Peripateticism.

During our hikes, we take advantage of the affinity and connection with nature to conduct live astronomical observations. We dive into the darkness of the night sky and use a small portable telescope to explore planets, constellations, star clusters, and other celestial phenomena. Through these experiences, our members not only acquire scientific knowledge but also cultivate a personal and emotional connection with the vast universe that surrounds us.

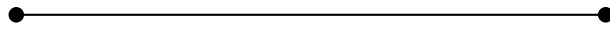
In addition to hikes, we also promote active learning through interactive and collaborative projects. Club members have the opportunity to explore computerized space simulations and participate in practical activities such as observing solar and lunar eclipses. These practical experiences allow them to apply the theoretical concepts they have learned, strengthening their understanding and stimulating their scientific creativity. Being a part of this astronomy club has had a significant impact on its members and resulted in a remarkable change in attitude toward the sciences, the universe, and everything around them. The wonderful world of astronomy is a gateway to awakening curiosity in club members, and curiosity is one of the essential ingredients of excitement.

Curiosity — what is different and stands out in the environment — ignites excitement. And with excitement, the windows of attention open, a necessary focus for the creation of knowledge. Nothing awakens curiosity more than inviting young people to explore the cosmos, helping them understand that comprehending the secrets of the universe is to know our own origin. This arouses curiosity and excitement, and emotions, ultimately, are the most important foundation for all learning and memory processes.

In summary, our approach to peripateticism in the astronomy club has revolutionized the way we teach and learn this discipline. By combining hikes, live observations, and practical projects, our participants not only acquire a profound knowledge of astronomy but also develop critical thinking skills, teamwork, and a lasting passion for exploring the mysteries of the cosmos.

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Astronomy Education: Planetarium and Museum Features

Presenter: Ekaterina Tikhomirova, SACI YR «Cultural and educational center named after Valentina V. Tereshkova», Yaroslavl, NAEC, the Russian Federation

The cultural and educational center named after V.V. Tereshkova houses a planetarium, a space museum, an Exposition Hall, an observatory, and an educational interactive classroom. In the following discussion, we consider astronomy education and enlightenment at the cultural and educational center.

Poster link: <https://doi.org/10.5281/zenodo.10445288>



The Planetaria are unique centers where educational and research activities are successfully combined. The cultural and educational center is a modern complex, encompassing a planetarium, a museum of the history of cosmonautics, an astronomical observatory and interactive classrooms for astronomical study groups.

At the cultural and educational center named after Valentina V. Tereshkova, there are astronomy and space education groups available for children and young people aged 7 to 23 years old. Attendance for all these groups of children and young people is free, as it is covered by the regional fund.

The astronomical clubs are for children aged 7 to 17 years old. Astronomical clubs operate for four years according to independently developed programs. In the first few years, children study constellations, the principles of orientation by stars, the Solar System, and later also the basics of astrophysics. The planetarium projects the starry sky observed in different parts of the globe regardless of the weather, at any time of the day and year. Besides the starry sky, there are ample opportunities for studying of Solar System, planets, comets, fireballs, meteor showers, and others. The deep sky objects can also be projected using specialized software and digital optical systems. The proper use of the grand demonstration opportunities of the planetarium, using traditional and innovative techniques, guarantees not only the high interest of spectators in the presented material but also the youth's attraction to activity in space and astronomical research. The astronomical observatory of the Center promotes the acquisition of practical skills for working with astronomical devices. High school students are engaged in solving Olympiad tasks and preparing research papers. They take part in the Russian Astronomy Olympiads, scientific conferences, and competitions.

The groups of Young Astronauts are engaged in exploration and research work, as well as the development of theoretical knowledge in the field of aviation, astronautics, and astronomy, using the richest material available to the museum "History of Cosmonautics" of Valentina Tereshkova Cultural and Educational Center and other museums. The members of these groups are children aged 12 to 16 years old. The goal of the educational program for children is to gain knowledge about space and learn how to apply it in life and then embark on the path of self-acquisition of knowledge and the pursuit of space exploration. The main disciplines of the 4-year course are cosmonautics, astronomy, physics, medical biology, and research activities. The children in Young Astronauts groups also prepare research papers and take part in meetings with astronauts and scientists, scientific conferences, and competitions.

The astronomical club «The Universe» is created in order to expand knowledge on astronomy, astronautics, natural-technical and humanities sciences, instill in students the skills of independent research work, the development of analytical abilities, acquaintance with the latest scientific discoveries in Russia and the world. The members of this club are mainly the State pedagogical university students who will become teachers of physics and astronomy. They prepare research papers and participate in international and Russian scientific conferences and competitions.

Astronomy is a unique discipline fostering the development of creative abilities through the creation of intellectual property objects by participants of astronomical clubs. Thus, at all stages of child development, we consider the main pedagogical technology to be the exploration and research work. The goal is not only an acquaintance with well-known knowledge about the Universe but also the acquisition of new knowledge for the very first time, the making of micro discoveries by children, and the presentation of their results at conferences and competitions. Annual conferences and competitions have been organized at the Center named after Valentina V. Tereshkova to cater also to the first stage so that students of different ages can present their research.

Regional children’s creative photo competition “The Sky and the Earth”. The main theme of the competition is a terrestrial landscape with celestial bodies and phenomena. The competition comprises four categories: the Earth and the Moon (phases of the Moon, lunar eclipses, etc), the Earth and the Sun (sunrise, sunset, eclipses), the Earth and the stars (starry sky, constellations, asterisms), and the terrestrial landscapes including rainbows, thunderstorms, clouds and other atmospheric phenomena (noctilucent clouds, meteors, fireballs, falling meteorites, auroras). Children from 7 to 18 years old can participate in the competition.

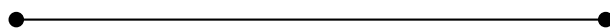
The conference “Road to the Stars” for schoolchildren (with international participation). The conference on astronomy and cosmonautics for schoolchildren, implemented in online and offline format, includes sections on “Research on astronomy and cosmonautics” and “Space museum studies and local history. History of Astronautics”. The Conference features two age categories for students from 11 to 14 and from 15 to 18 years old.

The International conference «Readings named after Valentina V.Tereshkova» is held annually at Cultural and educational center named after Valentina V.Tereshkova in March. It is dedicated to astronomy and space research in Russia and worldwide. The conference consists of three sessions: astronomy and cosmonautics research, space education and enlightenment, and astronomical education and enlightenment. Conference participants include astronauts, scientists, lecturers, teachers, as well as college and university students.

Subsequent stages of presenting children’s research work are conducted at events in other cities and countries, both online and offline.

References:

- [1] «Astronomical education in the Cultural and educational centre named after V.V.Tereshkova», E.N. Tikhomirova / X Serbian-Bulgarian Astronomical Conference, 30 May - 3 June 2016, Belgrade, Serbia, http://wfpdb.org/ftp/10_SBAC/xsbac_abstracts.pdf. 84



Trial of Various Astronomical Educational Applications in Japan, a Planetarium Nation

Presenter: Hidehiko Agata, OAO IAU & NAOJ, Japan

There are more than 350 planetarium facilities nationwide in Japan, with an estimated 9 million visitors per year. Planetariums have been important regional centers for astronomy education and promotion for the past 100 years. Their use in school education constitutes approximately 20% of their utilization. Moreover, mobile planetariums for school visits are now widespread and the educational content taught using planetariums is also diversifying. In the following, we would like to discuss some examples of this diversification.



Poster link: <https://doi.org/10.5281/zenodo.10445251>

This study will examine how modern planetarium equipment has contributed to astronomy education in Japan. There are more than 350 planetarium facilities nationwide, with an estimated 9 million visitors per year. Planetariums have been important regional centers for astronomy education and promotion for the past 100 years. Their use in school education constitutes approximately 20% of their utilization. Furthermore, mobile planetariums for school visits are now widespread and the educational contents taught using planetariums are also diversifying.

1. Quantity of Planetariums in Japan

In Japan, there are more than 350 planetarium facilities nationwide, with an estimated 9 million visitors per year. Of these, school education use accounts for about 20% [1]. For reference, the total population of Japan is approximately 120 million, which means that up to 7.5% of the population visits a planetarium facility at least once a year. This is the same level as the number of annual stadium spectators of the J-League soccer teams [2]. Planetariums have been important regional centers for astronomy education and promotion for the past 100 years (Fig.1). According to the results of a marketing survey by the Sora Tourism Promotion Council, there are 23 million people who would like to visit a Planetarium facility if given the opportunity [3].

2. Educational use of planetarium theaters in Japan

2-1 School education (including pre-school education)

“Learning projection” in planetarium theaters in Japan is used in kindergartens, elementary schools, and junior high schools. The main users are elementary school units. The contents of the learning projection at elementary schools are as follows.



Figure 1: Current Goto Planetarium equipment.

Fourth-grade elementary school: diurnal motion of the sun / diurnal motion of the moon / diurnal motion of stars, constellations, brightness and color of stars, as well as topics of interest to the students (planets, etc.)

Sixth grade: Mainly learning about the phases of the moon.

However, school units as “mobile classrooms” may offer programs on the latest astronomy, space, life, society, and human relations as general projections. Planetarium equipment at local children’s centers and other facilities may contribute to the creation of a “third place” for children.

2-2 Lifelong Learning

It is expected to become a center for local cultural activities and transform the traditional receiver-sender dynamic of an institutional space by encouraging the participation of local residents. (Participatory facilities)

2-3 Benefits of Planetarium Viewing

“Why did you get into science?” asked NAOJ staff, other researchers and related people. Researchers and engineers born in the 1950s answered: “We were influenced by science education books.” On the other hand, many researchers/engineers who were born after the 1960s answered: “Because of experiences at science museums, planetariums, etc.”

Here is one example.

“Thanks to the Kobe City Science Museum, I became interested in astronomy. I want to work in a planetarium after I retire.” This is a statement by Professor Eiichiro Komatsu (Director of Max Planck Astrophysics). (September 2013, at the latest astronomy dissemination workshop). Other similar statements were obtained from many other scientists.

3. Alliances with Academic Research

(1) Participation of Research Institutions

Example: At NAOJ (National Astronomical Observatory of Japan);

NAOJ started the 4D2U project in 2001 and has been operating a stereoscopic dome theater since 2007(Fig.2). 4D2U contents, including the space viewer “Mitaka” (creator: Dr. Tsunehiko Kato), are used at planetarium facilities around the world [4].



Figure 2: 4D2U Dome Theater (Credit: NAOJ).



Figure 3: Mobile planetarium (Credit: K. Karasaki).

(2) Lectures by researchers at planetarium theaters

The surround sound function of the Full dome allows you to enjoy a more powerful presentation than in an ordinary lecture hall.

(3) Creation of employment opportunities for young astronomers

(4) Use of authentic materials in astronomy

Providing free materials to planetariums is important.

Note that planetariums are already equivalent to dome theaters.

Note that it is not exclusively for astronomy.

4. Diverse Evolution: Use of Mobile Planetariums, etc.

(1) Visiting Hospitals across Japan with Mobile Planetariums

“Star Spinning Village” conducts outreach activities to bring the starry sky to those who cannot see the real stars due to illness, handicap, or environment, and to those who are far from information about the stars and the universe. By Takahashi & Atobe (2023) [5].

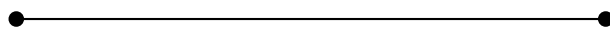
(2) Mobile planetarium visits to elementary schools

The mobile planetarium business in Japan started in 2003, and “Tokyo Mobile Planetarium Company” started its business in 2008 (model case). There are currently about 20 mobile

planetarium businesses in Japan that mainly target elementary schools and kindergartens (2023, from personal communication with Kenji Karasaki)(Fig.3).

References:

- [1] JPA Japan Planetarium Association <https://planetarium.jp/>
- [2] JFA Japan Football Association <https://aboutj.jleague.jp/corporate/management/attendance/>
- [3] Hidehiko Agata & Shoichi Itoh (2023), The Astronomical Herald (ASJ), Vol.116,241-247
- [4] 4D2U project NAOJ <http://4d2u.nao.ac.jp/english/index.html> (English pages)
- [5] Mariko Takahashi & Koichi Atobe (2023), The Astronomical Herald (ASJ), Vol.116,248-254



Communicating Astronomy Through Developing in-House Locally Customized Planetarium Shows - Experience

Presenter: Jayant Ganguly, Regional Science Centre and Planetarium Calicut, India

Developing a good planetarium show involves elements of 'Aesthetic Cognitivism.' It reveals aspects of understanding the nature of the objects in the sky, provides conceptual connections, and engages visitors in identifying themselves as a part of the physical whole — as 'stardust'. Here, the presentation style, the delivery, the light and shadow, the background music, the silence, the narrations and their density, the visual indicators and signifiers, the intention of the story developer, and many other aspects of the performance all matter. At Regional Science Centre and Planetarium Calicut (RSCPC), we developed 40 planetarium shows over a span of 27 years catering to the common adults, schools, and the culturally diverse public. This talk reflects upon our experiences and reflections.



Poster link: <https://doi.org/10.5281/zenodo.10445299>

Introduction

A planetarium is a specialized facility meticulously designed for the projection of celestial objects and phenomena, with a specific focus on stars, planets, and other celestial bodies in the night

sky. By utilizing advanced projection systems capable of faithfully simulating the night sky's appearance, it offers an immersive and enlightening experience.

Planetarium Shows

Planetarium shows feature captivating educational presentations held within these unique establishments. These presentations ingeniously employ a blend of visual and auditory effects to recreate the majesty of the night sky, effectively guiding the audience on a cosmic journey.

The Art of Crafting Planetarium Shows

The development of an exceptional planetarium show is an intricate blend of art and science. It reveals a profound understanding of celestial objects and their intrinsic nature. Moreover, it provides mental representations, conceptually engaging viewers and aiding them in drawing meaningful connections.

Our planetarium's repertoire of shows caters to a diverse audience, spanning middle, secondary, and senior secondary school students, as well as primary school children and the culturally rich and diverse public found within our demographic.

The Craftsmanship of Planetarium Show Development

Our approach involves translating astronomical knowledge into immersive audio-visual projections on the planetarium dome. The goal is to create an experience that resonates with our visitors and enhances their understanding of the cosmos.

Tailoring the presentation style to meet the specific needs and beliefs of the local population is pivotal. Factors such as delivery, lighting, background music, narrations, and visual elements all play a crucial role in ensuring the content is both engaging and relevant.

A planetarium becomes a focal point for a specific demographic, one that returns frequently to deepen their understanding and connection with the subject matter.

Innovative Planetarium Shows

1. "Mahabali, Keralam, and the 'ONAM' Show" Kerala, a southern state in India, celebrates the festivals of Visu and Onam with great enthusiasm. These festivities are rooted in culture and mythology. The festival of Onam features elaborate floral carpets, which possess significant astronomical symbolism. Onam is celebrated in the Malayalam month of Chingam when the moon is near the Attam nakshatra. We've developed a planetarium show that elucidates the celestial criteria integral to the celebration of Onam.

2. "Malabar, Ramzan, and Islamic Astronomer" Kozhikode and its adjacent Malappuram district boast a substantial Muslim population. Ramzan is one of the famous festivals celebrated by Muslims globally. Literally, the "Festival of the Breaking the Fast", Eid-al-Fitr is one of the two important Islamic celebrations — the other is related to Hajj, the pilgrimage to Mecca. Since Islam observes a lunar calendar, the official start of the festival occurs at different times around the globe, based on when the crescent moon is first seen. Our planetarium show delves into the astronomy behind the festival and highlights the contributions of Islamic astronomers to the broader field of astronomy.

Islamic astronomers have played an instrumental role in developing concepts such as celestial nomenclature and astronomical instruments like astrolabes. Many stars bear Arabic names like Algol, Deneb, Betelgeuse, Rigel, Aldebaran. Terms like Zenith, Nadir, Albedo, and Azimuth

are Arabic in origin. Those astronomers have developed and refined quadrants and astrolabes. Islamic astronomer al-Khwarizmi performed detailed calculations of the Sun, the Moon, the planets, and the eclipse.

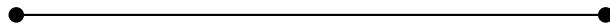
Astronomy helped Muslims to solve some of the problems relating to prayer timings, ascertaining festival dates, and identifying directions. Furthermore, one of the major achievements by Islamic astronomers which solved a pressing issue for the community is the development of a “cartographic grid from Mecca”.

The planetarium show titled ‘Ramzan and Islamic astronomy’ was developed to explain the astronomical criteria of the Ramzan festival and highlight the contributions of Islamic astronomers to astronomy in general, such as how they addressed their societal needs using ideas incorporating the motion of the Sun and the Moon.

3. “Astro Adventures with Superman” – A Show for Children For school children visiting our planetarium, complex presentations designed for a mature audience may be challenging to comprehend. To engage young minds, we’ve designed a storyline where children embark on astronomical adventures with iconic comic book heroes, such as Superman. These stories simplify fundamental astronomical concepts, making them accessible and enjoyable.

Conclusions

The development of creative and audience-specific planetarium shows, elucidating various aspects of astronomy, transforms the planetarium into a powerful medium for mass communication in the field of astronomy.



Bridges Between Cultures: Activities and Meetings About Cultural Astronomy (NASE)

Presenter: Beatriz Garcia and Ricardo Moreno, NASE. National Technological University, Faculty Mendoza, Argentina; and Colegio Retamar, Madrid, Spain

Collaborators: Rosa M. Ros, Univ. Politécnic, Barcelona, Spain, and Ederlinda Vinuales, Univ. Zaragoza, Spain

To commemorate the UNESCO International Day of Light, NASE proposes to all its participants, instructors, and referents to carry out simple experiences of great educational interest. Although the day of light is May 16, the activities can be conducted between the March and September equinoxes. The idea started in 2018 when we invited people to take measurements and perform the Herschel experiment to detect infrared light. The project continued each year focusing on different topics, connecting astronomy and everyday life. This new approach to concepts of Cultural Astronomy has resulted in two meetings each year: the “Bridges Between Cultures” and “NASE”. We present here some results of these activities and we will show how simple experiences can transform the life of a lot of people around the Globe.



Poster link: <https://doi.org/10.5281/zenodo.10445227>

To commemorate the UNESCO International Day of Light, NASE (Network for Astronomy School Education) proposed to all its participants and instructors to carry out simple exercises of great educational interest. Although the day of light is May 16th, the activities can happen anywhere between the March and September equinoxes. The idea started in 2018 when we invited people to take measurements and perform the Herschel experiment to detect infrared light. The project continued each year focusing on different topics connecting Astronomy and everyday life:

- 2019 **Solar Power**: Using an oil spot photometer, we could measure the power of the Sun by comparing it to, for example, a 100 W light bulb.
- 2020 **Parallel Earth**: We reproduced the illuminated areas on Earth (day and night and the seasons) on an outdoor globe, oriented in the same way as the Earth and illuminated by the same light source: the Sun.
- 2021 **Herschel's Experiment**: The goal was to repeat the experiment from 1800, through which the famous astronomer William Herschel discovered a form of radiation different from visible light, using a glass prism, four thermometers, and a cardboard box.

- **2022 Latitude for Traveling and Navigation:** the NASE program proposed a return to the origins, inviting everyone to understand how the “Silk Road” emerges between two parallels. By following cities that are more or less on the same latitude, it moves quickly from East to West, which also demonstrates how Columbus was able to reach America by sailing without references by attempting to remain on the same parallel. The experiment consisted of measuring our latitude with a quadrant made of cardboard. During the night, measuring the altitude of the North Star in the northern hemisphere, and in the southern hemisphere measuring the altitude of the point corresponding to the South Pole. And during the day, measuring the altitude of the Sun, when it passes through the meridian of the place.
- **2023 Looking for Micrometeorites:** The project consisted of recovering micrometeorites with a magnet from the material deposited in gutters and road ditches or in the schoolyard. The micrometeorites were recovered using an outdoor tray by moving near the surface with a cup that had a magnet inside. The micrometeorites were identified with the camera of a cell phone as spherical and dark pearls. It was a very impressive experience for young students to discover that they had ET material in their hands.

The project involved various activities: there are many reports, photos, and comments from participants of the final festival and from the online session too.

This new approach to concepts of Cultural Astronomy has resulted in two meetings each year, the “Bridges Between Cultures” and “NASE+”. We present here some details about “Bridges Between Cultures” and we show how simple experiences can transform the life of a lot of people.

The final events were at the International Festival Ciencia en Accion (Science on Stage – Spain). Every year, three or four tents were installed in the middle of the host city. They were visited by local students (more than 300 from 10 institutions) and people that were walking through the city, who also participated in the activities. Every year, many teachers from about 10 different countries (Africa, America, Asia and Europe) are invited to the final event, included the Big Experience.

In recent years, several hundred teachers have participated and more than a thousand student (10-18) reports have been sent. A Summary Book as well as student reports were published and can be found on the website of NASE (naseprogram.org).



Figure 1: A blind participant measures the power of the Sun using her cheek in Spain (2019).



Figure 2: Measuring the latitude in Togo (2022).



Figure 3: Parallel Earth in Indonesia (2020).



Figure 4: Looking for micrometeorites in Argentina, (2023).

Exploring the Frontiers of Space in 3D

Presenter: Chris Impey, University of Arizona, USA

Collaborators: Alexander Danehy and Matthew Wenger, University of Arizona

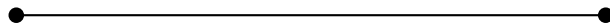
Immersive virtual reality provides an excellent way to experience astronomy facilities that the public generally cannot visit. Epic Games' Unreal Engine has been used to create a 3D exhibit where visitors use a game controller to walk their avatars among cutting-edge optical and radio telescopes, with the Hubble and James Webb Space Telescopes hovering overhead. Several of the telescopes are animated. OSIRIS-Rex is seen next to a detailed and suitably scaled rendition of the Bennu asteroid, and part of the virtual real estate is textured as a Martian surface with several Mars missions included. Visits are self-guided with interactive posters giving the main scientific results of the various telescopes and missions.



Poster link: <https://doi.org/10.5281/zenodo.10445333>

The poster describes a new immersive 3D experience to let the public experience the scope and scale of major telescopes and space missions. Visitors explore the virtual reality (VR) world through the first-person view of an avatar surrounded by mountains and below a realistic

starry sky. The experience includes large telescopes built at the University of Arizona, along with planetary missions and space telescopes suspended above the sky platform. Billboards and posters describe the facilities and their science goals, so the tour can be self-guided. The environment was built with Epic Games' 3D visualization engine, the same engine behind the popular online video game Fortnite. It is delivered using an Oculus Quest headset tethered to a laptop gaming computer, or at somewhat lower resolution using standalone headsets. Facilities in the 3D experience include the 6.5-meter MMT, the 2 x 8.4-meter Large Binocular Telescope, a 15-meter radio dish from the Event Horizon Telescope, and the Giant Magellan Telescope, which has an equivalent diameter of 24.5-meters and will soon be the largest telescope in the world. The Hubble Space Telescope and the James Webb Space Telescope are both represented. Many of the 3D models are animated, showing the slewing of the large optical telescopes, deployment of lasers for guiding, and unfurling of the solar panels of the James Webb Space Telescope. Planetary probes include the HiRISE orbiter and the Phoenix lander, set on a Martian landscape, and OSIRIS-REx, shown near a detailed, suitably scaled model of the 500-meter Bennu asteroid. The exhibit has been deployed at SXSW 2022 in Austin and at a fund-raising event in Washington, DC. It can readily be expanded with additional 3D models or customized for other major observatories. Virtual reality gives public participants an immersive and visceral sense of cutting-edge astronomy facilities and allows them to visit major telescopes that they could not visit in the real world.



Creating Astronomy Festivals at Outdoor Concerts and Tourist Sites (US National Mall with Monuments and Museums) - 100,000 People Participated

Presenter: Donald Lubowich, Coordinator of Astronomy Outreach, Hofstra University, Hempstead, NY, USA

I describe how to create large astronomy festivals: I explain how to organize large astronomy festivals like Music and Astronomy Under the Stars (MAUS), which was funded by NASA and attracted 70,000 people, featuring 75 concerts. This event typically drew 60% families, many with young children, and had a 60% female attendance rate, with about 20% seniors. The concerts were mostly free and held outdoors, with some organized by underserved communities. Another example is The Astronomy Festival on the National Mall (AFNM), which was co-sponsored by the White House in 2010. These feature: solar and optical telescope observations; live-image projection; posters/banners/videos; demos, hands-on activities; citizen science projects; as well as info on discoveries, careers, and science museums. AFNM is the largest annual astronomy outreach event in the US (30,000 people, 4-5 K/yr) with 120 educators from 30 scientific institutions, universities, and astronomy clubs (AAAS, AAS, AGU, APS, NASA, NASM, NOAA, NOAO, NRAO, NSF, The Planetary Society, STScI, Sky and Tel, USNO). Yo-Yo-Ma, the Chicago and Boston Symphony Orchestras, Ravi Coltrane, Phish, Blood Sweat and Tears, Deep Purple, Patti Smith, James Taylor, and Wilco performed at some MAUS events (1000 - 25,000 people/concert).



Poster link: <https://doi.org/10.5281/zenodo.10445323>

Bringing astronomy directly to the public:

Participation in outdoor concerts, festivals, and fairs reached 70,000 people.

There were 100 person-hours per event. The set-up was at 6:30, the start at 7 pm, the concert started at 8 pm, followed by star gazing from 10 to 11 pm. More activities/demos were organized during daylight than at nighttime.

Guaranteed large attendance

- Astronomy outreach program at parks before, during, and after outdoor concerts, festivals, and at intermission

- Audiences at mostly free concerts in the parks have made a commitment to be outside at night for several hours
- From 800 - 35,000 people attend a concert or festival
- Up to 5000 people/event get involved with astronomy
- Audience does not regularly visit science museums, planetariums, or star parties (based on our survey)
- Different types of music selected to increase diversity: classical, folk, rock, pop, opera, county-western, and Latin music.
- Performers included: Yo-Yo-Ma, Chicago and Boston Symphony Orchestras, Ravi Coltrane, Esperanza Spalding, Phish, Blood Sweat & Tears, Deep Purple, Patti Smith, Tony Orlando, Debbie Boone, James Taylor, and Wilco
- 60% of the audience is female; 20% are seniors
- Families with young children come to these events, which enabled many children and their parents to look through a telescope for the first time!

Logistics: work with parks/festivals to Identify MAUS events; select location to maximize participants; dates selected after performers and schedules arranged; select weekend nights and dates with interesting astronomical events; work with local astronomy clubs; promote local science museums and planetariums; work with organizations representing underserved groups, plan for success and problems; cloudy weather programs; publicity and social media; use signs and flags to identify location within the parks; test equipment, easy set-up; add www links and QR codes to posters/hand-outs.

Promotes: follow-up STEM activities; membership in astronomy clubs; citizen science projects.

MAUS Evaluation: 96% of the participants of all ages, ethnicities, income groups, or directions of interest in science found MAUS enjoyable and understandable; learned about astronomy; wanted to learn more; and increased their interest in science (average rating 3.35/4, 4 = strongly agree). The positive response was the same for all genders and all types of music.

MAUS response: “I saw today stars that I would have never seen ever. It was a wonderful event at Jones Beach. I hope to keep doing it again. It was phenomenal. The people were wonderful, the way Hofstra put this event on. I’m really glad, and I thank them. I find it amazing, and I want to go home with the literature, and I want to go on the internet and look into it, and I want to learn more. I really find it beautiful, and I’m glad you exposed us to it.” LYNN R.

Astronomy Festival on the National Mall - the largest annual astronomy outreach event in the US with 30,000 participants (up to 6000/yr), 30 organization, and 120 astronomy educators

Astronomy Festival on the National Mall is the largest annual astronomy outreach event in the US, with 30 organizations and 120 astronomy educators participating. It started as a MAUS event (concert on the Mall). Initially participants were people who came to the National Mall. Now, the AFNM is a family destination, and people come specifically for the Astronomy Festival. The AFNM partners with the Smithsonian for their Solstice Saturday programs and performances (mostly non-science museums).

AFNM requires: securing funding; months of planning; obtaining required permits; table/chair/generator rental; insurance; emergency medical personal; portable toilets; coordinating with science organizations, museums, U.S. Government, astronomy clubs, and amateur astronomers; obtaining a rain location; parking; publicity; social media. **Can be adapted to other high profile tourist**



Figure 1: Looking at Saturn, Chicago Symphony Orchestra, Holts' The Planets.



Figure 2: Large crowd for the AFNM.

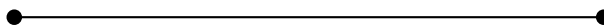
sites!

Participating Scientific Organizations: AAAS, AAPT, AAS, AGU, APS, ASP, Ball Aerospace & Technologies Corp, Carnegie Science, Chandra X-ray Center, Dark Sky International, Johns Hopkins University/Applied Physics Laboratory, Lunar and Planetary Institute, NASA, NOAA, NOAO (NSF's NoIRLab), NRAO, NSF, U.S. Naval Research Laboratory, The Planetary Society, NASM, Smithsonian, Society of Physics Students, Space Telescope Science Institute, U.S. Naval Observatory. **Colleges and Universities:** American University, Catholic University of America, Georgetown University, George Mason University, George Washington University, Montgomery College, Penn State University, Rice University/E-planetarium show in dome, U. Maryland, U. Virginia. **Astronomy clubs:** Goddard Astronomy Club, Northern Virginia Astronomy Club, National Capital Astronomers.

AFNM response: "I want to thank you for organizing the AFNM. My daughter and I had the opportunity to attend, and she had a great time checking out the telescopes, information tables, and activities. I picked up a few pairs of eclipse glasses, and was able to use them in Dayton, Ohio, where I teach Physics, Honors Chemistry, and AP Biology. I teamed up with a math teacher, and through the day over 300 students (and a few faculty) had the opportunity to observe the Sun and the eclipse while we talked about phases of the moon, eclipses, and seasons. I just wanted to thank you for the impact this event had on my daughter (who, at age 8, tells people she wants to be an astronomer and study space) and the 300+ students at my school who were able to see the eclipse." 2017, Christina O'Malley, Ph.D., Carroll H.S.



Figure 3: Long lines for free planetarium show at the AFNM.



Stargazing to Star-Teaching: Effective Approaches for Astronomy Education in Action

Presenter: Amoghavarsha N, Indian Institute of Astrophysics, India

Collaborators: R. Punith, IIA, Niruj Mohan Ramanujam, IIA, B. S. Shylaja, Jawaharlal Nehru Planetarium, S. Seetha, Raman Research Institute, Annapurni Subramaniam, IIA

“COSMOS” is the upcoming world’s first commercial 8K-resolution LED dome planetarium in the city of Mysuru, Karnataka, India. While awaiting construction, the IIA has started a comprehensive education and outreach program in the city and its neighbourhoods. One of the main objectives is to use the LED dome to train students in data analysis using current data from telescopes, as well as to incorporate all major STEM events. We have started education and outreach programs in the district and aim to extend them to neighbouring districts as well. We are building a common platform for educators, science communicators, and other stakeholders in the area. In this talk, I will describe our programs, methodology, and their efficacy and end with future plans to use the facilities of the planetarium.



Poster link: <https://doi.org/10.5281/zenodo.10445314>

The Cosmology Education and Research Training Centre (COSMOS) is an upcoming LED Dome planetarium and a research training centre in the city of Mysuru, Karnataka, India. This will be

the world's first independent 8K resolution LED dome planetarium, which is the next big leap in planetarium technology.

The Indian Institute of Astrophysics (IIA) has started a comprehensive education and outreach program in Mysuru city and its neighbourhood well ahead of the construction of the planetarium. The general objectives of the program are to promote interest in astronomy and STEM in general, to partner with planetaria across India, to be a hub for STEM training in a dome and a skill development centre for science teachers, to develop a scientific temper among the public, to propagate rationality and critical thinking, and to provide a platform for students to program their own shows for the LED Dome. In addition, some unique features of the program include using the LED Dome for data visualisation and analysis in various fields of STEM — in particular, utilising data from Indian telescopes — and to focus on astronomy popularisation in the Kannada language and in the rural areas of the state of Karnataka.

The outreach efforts of COSMOS Mysuru stand on six pillars: astronomy in the public domain, introducing astronomy at the university and college level, unearthing medieval-era astronomy in the Kannada language, Citizen science workshops, Science and education workshops, and Rural and urban school education.

The city of Mysuru, though close to the astronomy hub of Bengaluru, lacks an academic ecosystem of astronomy. Our initial efforts have gone into creating it. Most importantly, we have established ties with many collaborators in the region who work on popularising astronomy and science. One of the main challenges is to introduce concepts of astronomy in rural areas and build a capacity for the schools and colleges, both urban and rural, to use the novel features of the LED Dome planetarium when it becomes operational.

Apart from the special lectures, workshops, and demonstrations at schools and colleges, the outreach team of COSMOS has been reaching out through activities like hands-on low-cost/no-cost experiments for students and the public. We have been organising public events like skywatching and stargazing, eclipse watching, Asteroid Day, Zero Shadow Day, and Astronomy quizzes in informal public settings such as libraries, cafes, open grounds, etc. Reserving the highly academic language to a formal setting, the events and programs in informal settings used the local speaking language and easy words of the English language, widely known to all.

The academic talks and workshops, organised for the undergraduate and postgraduate students of Mysuru, have led to discussions to introduce a full-fledged elective course in Astronomy from the next academic year at the University of Mysore.

A plan of action has been prepared after careful evaluation of the activities in the first year. We have started our work to team up with the 6000 rural libraries run by the Panchayat Raj Department, Government of Karnataka. Together, we are looking forward to conducting Astronomy events and festivals in the public domain. While waiting for the planetarium facilities to come up, we intend to form more than 100 Astronomy clubs across Karnataka and conduct teachers' training workshops on astronomy.

Another unique project under the COSMOS initiative aims to identify, collect, digitise, transcript, and translate astronomy-related materials in and around the Old Mysore province in Kannada, originating from the 17th to 19th century. In the quest for records and documents, the team



Figure 6: Mr. Amoghavarsha N, delivering a talk on the fundamentals of astronomy to the children of Police officials (Left Image), Amateur astronomers and the city's public gathered for a sky-watch event (Right Image).

has found more than 40 previously unstudied manuscripts in many local archives, written in a variety of older scripts and languages. These manuscripts are being identified among thousands of palm leaf and paper manuscripts, then transcribed, translated, and analyzed with the help of linguistics experts. These materials will be published online as a resource for students and researchers in the years to come.

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Unveiling the Celestial Narratives: Empowering Human Resources Through Literary Exploration

Presenter: Muchammad Toyib, Master Program of Human Resource Development, Postgraduate School of Universitas Airlangga; Surabaya Astronomy Club; East Java Amateur Astronomer Communication Forum (FOKALIS JATIM), Indonesia

“Unveiling the Celestial Narratives: Empowering Human Resources through Literary Exploration” synergizes amateur astronomers and literary engagement to elevate education and personal growth. By blending science and writing, we nurture scientific literacy, critical thinking, and cross-disciplinary skills. Collaborative narratives bridge complex concepts and emotional resonance, fostering understanding and curiosity. This unique initiative also fosters cross-cultural connections, uniting diverse communities under the celestial canopy. Ultimately, we present a transformative model that enriches Indonesia’s human resources, offering a profound cosmic perspective and nurturing a vibrant, interconnected society.



Poster link: <https://doi.org/10.5281/zenodo.10445343>

Introduction

In the second largest city of Indonesia, Surabaya, a unique initiative is taking shape, one that seamlessly merges the realms of science and literature to create a transformative educational experience. “*Surabaya Punya Cerita Astronomi*” (Surabaya Has an Astronomical Story) is a groundbreaking project that harnesses the power of literary engagement and amateur astronomers’ expertise to elevate education and personal growth in the city by holding a national level essay competition. This initiative not only bridges the gap between scientific knowledge and the public but also fosters a deep sense of understanding, curiosity, and connection among diverse communities under the vast celestial canopy.

Synergizing Science and Literature

At the core of this initiative lies the synergy between science and literature. By blending the analytical precision of astronomy with the creative depth of writing, the project cultivates scientific literacy, critical thinking, and cross-disciplinary skills among participants. Through seminar and collaborative writing sessions, amateur astronomers and aspiring writers come together to explore the celestial narratives that have fascinated humanity for centuries. This unique blend not only enriches the participants’ knowledge of the universe but also nurtures their imagination, encouraging them to explore the cosmos through the lens of literature.

Nurturing Understanding and Curiosity

Collaborative narratives, crafted by the amalgamation of scientific facts and literary prowess, serve as bridges that span the chasm between complex astronomical concepts and emotional resonance. Through these narratives, seemingly daunting ideas become accessible, relatable, and engrossing. Readers are not just presented with facts and figures but are invited into a world where the wonders of the universe are intertwined with human experiences. This approach fosters not only a profound understanding of celestial phenomena but also a deep curiosity to explore further, encouraging a lifelong pursuit of knowledge.

Fostering Cross-Cultural Connections

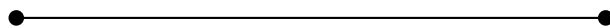
One of the remarkable aspects of this initiative is its ability to foster cross-cultural connections. The celestial narratives, rich with diverse perspectives and cultural nuances, unite people from various backgrounds and beliefs. Under the shared awe of the night sky, individuals from different ethnicities, religions, and social strata find common ground. This unity not only strengthens social bonds but also promotes a culture of inclusivity and acceptance, essential elements for a harmonious society.

Conclusion

“Surabaya Punya Cerita Astronomi” presents a transformative model for education and personal growth in Indonesia. By integrating science and literature, this initiative enriches the country’s human resources, offering a profound cosmic perspective that transcends boundaries and nurtures a vibrant, interconnected society. Through the collaborative efforts of amateur astronomers and aspiring writers, this project not only unveils the mysteries of the universe but also illuminates the path towards a more enlightened and unified future for Indonesia.

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Facts to Equations & What!/Wow! to How?

Presenter: Chrisphin Karthick, Indian Institute of Astrophysics, India

While planning to educate astronomy outside the classroom, we must first distinguish with whom we teach, in what environment, etc. If the audience is still in the educational stage, they can pursue it as a career path, while others can enjoy it as a hobby and raise awareness. Besides organizing regular talks and models, etc., we can engage them in working with maths, physics, and problem-solving activities related to astronomy and space education in a fun way. We have to differentiate between learning facts and analytical thinking. Using models and similar devices in explanations helps listeners discover the truth and facts, but working with the problem itself induces their analytical thinking with enthusiasm. Hence, either way, this enables the interest in astronomy to rise and is also good for stimulating analytical thinking.

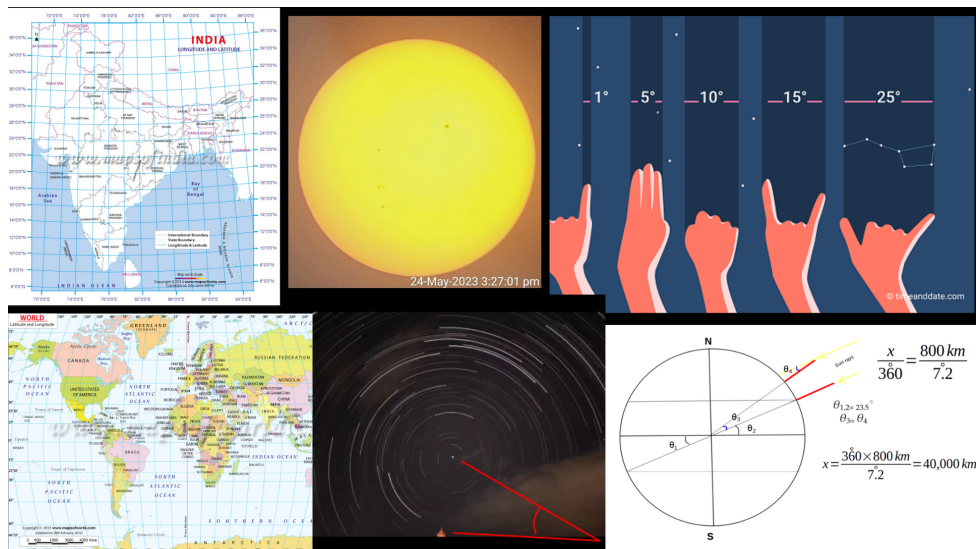


Poster link: <https://doi.org/10.5281/zenodo.10445351>

In this poster, I discuss such examples and how to execute them. Since we are speaking within an international context, we have to consider three categories: developed countries, developing countries, and under-developed countries. When the goal is to improve employment opportunities or raise scientific awareness, for countries like India and developing countries, we should plan the outreach to reach them in the right way to get them into the scientific world or make them skillful so they survive in any given situation. Most of the time, they are attracted to astronomy because they are addicted to or fascinated by science fiction movies, documentaries, etc. But it is our responsibility to make them good at problem-solving, logical and reasoning skills to survive in any job market, or leave them with the scientific awareness for the betterment of society, or identify their talents and make them contribute significantly to the scientific world as well as retain the science knowledge in order to share it with the next generations.

Considering all of the above, a few examples are discussed: (a) whatever the country we live in, we have our timing. Hence, timing differs as per the Greenwich Mean Time, with the representation such as +5.30 GMT for India. However, many people need to be made aware, that it comes from the simple time calculation of the rotation of the Earth. (b) We don't only need to engage with nighttime astronomy, we can also engage with daytime astronomy to capture the Sun's image with proper solar filters. This is also useful when celestial objects are not available, due to cloudy weather or timing unavailability, etc., at night. In such cases, we can encourage them to observe sunspots, monitor their daily variations, and pursue scientific inquiry based on their observations. Furthermore, we can engage them with zero shadow day experiments for

Example	Facts/What/Wow!	Equations/How?
1	The longitude of the place /India is 79.5 deg E or +5.30 GMT / UTC. By knowing one fact we can find the other.	$\frac{\text{Distance covered}}{\text{Time}} = \frac{360 \text{ deg}}{24 \text{ h}} = \frac{15 \text{ deg}}{1 \text{ h}}$
2	We can observe the sunspots through the telescope using proper solar filters. And that helps to find the angular rotation velocity of the sun.	$\text{Ang. vel. Sun} = \frac{\text{Displacement Sun spot}}{\text{Time}}$
3	Using our fingers, we can measure the Moon's and celestial objects' size - in distance.	$\tan 0.5 \text{ deg} = \frac{\text{Moon diameter } (d)}{\text{Moon Earth distance } (x)}$
4	The latitude and direction in the sky can be identified.	By observing the star trailing using Mobile/DSLR camera by exposing into longer time. The angle between pole star and horizon is the latitude of the place.



the latitude regions between + and - of 23.5 degrees and repeat the Eratosthenes experiments in modern times. (c) We can also introduce angular size measurement in the night sky astronomy. For example, the Moon covers 0.5 degrees. Using simple trigonometric equations, we can calculate the diameter of the Moon. Also, we can explain the equations regarding the limitations of the telescope and angular resolutions, and relate them to optics subjects, etc. (d) To identify the latitude of their place of observation, we can use our mobile camera / DSLR camera clicks for stars trailing towards the northern direction. This star trailing happens at the centre of some particular point. So, that centre point is the pole star, and the trailing direction is only from East to West. The angle to the horizon of the place is nothing else but the latitude of the place. So this approach differs from our traditional way of showing the planets (Jupiter, Saturn) and the Moon alone, and encourages the audiences to think.

Thus, we can ignite young minds towards another perspective of approaching astronomy other than simply being fascinated by it. This approach helps foster analytical minds and directs them toward astronomy, which helps create a good community of earthlings, both in their professional and personal lives from a global perspective. It also fosters peace among nations and care for our Earth as the only home to protect, live, and love.

DISCUSSION SUMMARY

The discussion of the session extended far beyond conventional educational spaces, showcasing initiatives that reached across geographic and cultural barriers. Projects spanning Egypt, Bahrain, Mexico, and various countries utilised engaging workshops, hand-on projects, and non-traditional venues like nature reserves and youth clubs. International collaborations leveraged technological advancements to democratise access to astronomical knowledge and experiences, echoing the importance of global partnerships in educational outreach.

Connections emerged between talks and posters, spotlighting common themes critical to effective astronomy education. These themes encompassed the utilisation of virtual reality, leveraging social media, and integrating cultural narratives to enrich the learning experience.

Community involvement, diverse teaching methodologies, and cultural elements surfaced as pivotal in nurturing curiosity and engagement among learners. Projects such as Skype a Scientist and the GWAM initiative serve as crucial bridges between classrooms and scientists, providing high school students with collaborative and research-oriented educational opportunities. The emphasis on astronomy's societal impact reverberates across numerous initiatives. GalileoMobile's work with refugees, The Travelling Telescope's extensive outreach in Kenya, astronomy programs tailored for marginalised Brazilian communities, and the Astronomy for Equity initiative's global outreach to underprivileged communities collectively highlight the substantial social influence embedded within astronomy education and outreach.

Moreover, the session emphasised the pivotal role of astronomy museums as catalysts for exploration and transformative learning. Talks showcased the rejuvenation of observatories, engagement of high school students in research initiatives, and exhibitions to foster scientific literacy. Museums emerged as dynamic hubs capable of engaging diverse audiences across varied cultural landscapes.

The thematic breadth encompassed various facets, including the engagement of amateur astronomers, initiatives targeting marginalized communities, the impact of school astrophotography contests, and the influential reach of astronomy exhibitions. Together, these presentations exemplified a vibrant and evolving landscape of astronomy education, highlighting technology, inclusivity, community engagement, and innovative teaching methods as key drivers in expanding the frontiers of cosmic understanding beyond conventional educational realms.

In essence, the session served as a celebration of collaborative endeavors and pioneering initiatives propelling advancements in astronomy education. It championed curiosity, inclusivity, and innovation as indispensable pillars guiding the exploration and dissemination of astronomical knowledge and our place in the universe beyond the confines of traditional educational paradigms.

Teaching Methods and Tools

Session organisers: Niall Deacon (OAE Heidelberg), Edward Gomez (LCO, UK), Beatriz García (Network for Astronomy School Education – NASE), Shylaja B S (Jawaharlal Nehru Planetarium)

SESSION OVERVIEW

How can educators most effectively teach astronomy content? This is a broad question that depends on the content, education level, and resources available to the teacher. In this session, we heard about the many innovative ways astronomy is being taught, with practical tips on how to implement them. This could be through simple demonstrations, naked-eye observing, online projects, astronomy education resources, using real scientific data in the classroom, or remote observing as well as teaching methods developed to reach diverse audiences.



TALK CONTRIBUTIONS

Virtual Reality in Astronomy Education: Reflecting on Design Principles

Speaker: Magdalena Kersting, Department of Science Education, University of Copenhagen, Denmark

Collaborators: Jackie Bondell, OzGrav, Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, Australia; Rolf Steier, Department of Primary and Secondary Teacher Education, Oslo Metropolitan University, Oslo, Norway; Mark Myers, OzGrav, Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Hawthorn, Australia

Virtual reality (VR) offers transformative possibilities for astronomy education, enhancing visual representation, engagement, and hands-on experiences in formal as well as informal settings. While many studies focus on the learner's view, this study emphasizes the often-neglected perspective of education and public outreach (EPO) professionals. Through focus group interviews and reflective dialogues with EPO experts and scientists from the Australian Research Council Centre of Excellence for Gravitational Wave Discovery, we identify design principles for integrating VR into astronomy education. These principles address immersion, visualization, facilitation, and collaboration, offering guidance for astronomy educators and deepening our understanding of the new VR learning contexts in astronomy.



Talk link: <https://youtu.be/yFSNIKD80M8>

In this summary and in the conversation that will occur at the conference, we will expand upon these principles, discussing their practical applications, implications, and potential for future research. The contents of this conference talk build on a recently published paper (Kersting et al., 2023).

Introduction

VR technologies offer a promising avenue for enriching astronomy education. The elusive nature and massive scales of astronomical concepts make them challenging for learners to grasp. However, the capabilities of VR for immersion, visualisation, collaboration, and facilitation can make these complex ideas more accessible (Kersting et al., 2021). Although research is growing

on the efficacy of VR in astronomy education, few studies have examined the perspectives of EPO professionals who design these VR experiences, including their experiences with and motivation to employ VR in astronomy education. These perspectives are crucial for understanding how to integrate VR into astronomy education in a meaningful way. In response, this study answers three research questions (RQs):

RQ1. What characterises the motivation of EPO professionals to use VR in astronomy education?

RQ2. Which opportunities and challenges of VR astronomy education guide the development and facilitation of VR astronomy experiences?

RQ3. Reflecting on the findings from RQ1 and RQ2, what design principles can be formulated to develop and use VR in astronomy education?

Background and methods

This study is interdisciplinary, incorporating astronomy, education research, and technical design expertise. It aims to go beyond direct educational practices to formulate broader design principles. This involves articulating the tacit knowledge in designing and analysing VR educational experiences. The study draws inspiration from Schön's (1983) concept of reflective practice, which distinguishes between 'reflection in action' (thinking while doing) and 'reflection on action' (thinking after doing). Reflective practice has been adapted in various fields, including informal science education, proving its enduring relevance.

We employed a two-step analytical approach involving thematic analysis of focus group interviews and reflective dialogues. The first step focused on understanding the motivation of practitioners (RQ1) and identifying the challenges and opportunities in VR astronomy education (RQ2). We used two semi-structured focus group interviews, one with the EPO team of OzGrav, the Australian Research Council Centre of Excellence for Gravitational Wave Discovery, and another with OzGrav scientists who volunteered as VR guides. The second step targeted RQ3, which aims to formulate design principles for VR in astronomy education. It involved reflective dialogues with two outreach professionals, lasting 60 minutes each. These dialogues took the findings from the thematic analysis as a starting point and were framed as acts of reflective practice. They served a dual purpose: reflecting on past EPO activities and developing new design principles. This dialogic approach allows for the synthesis of diverse expertise and contributes to articulating design principles for VR astronomy education.

Findings and discussion

Our findings reveal several factors motivating EPO professionals to use VR in astronomy education, including the aim for a significant educational impact and relevance for their audience. Other motivations include a passion for science, the desire to inspire young learners, and an affinity for VR technology. These align with the perspective of informal science education as an experiential and emotional endeavour aimed at shared meaning-making (Davies et al., 2019). In this context, VR can link experts' knowledge and passion, and learners' experiences (Kersting, Steier et al., 2021).

Opportunities in using VR for astronomy education include its versatility, visualisation capabilities, and potential for collaboration. The flexible VR setup allows for tailored learning experiences, and vivid visual representations create engagement. Its immersive nature particularly enhances learners' tangible and memorable encounters with astronomical phenomena, corroborating existing research (Atta et al., 2022; Madden et al., 2020; Severson et al., 2020) that identifies

VR learning environments as authentic and engaging. Our study also highlights the value of collaboration, with scientists benefiting from their roles as VR guides. However, there are challenges in using VR for astronomy education, such as safety considerations and the need for a balance between visual richness and scientific accuracy.

Our reflective dialogues have culminated in design principles centred around immersion, visualisation, collaboration, and facilitation. Kersting et al. (2023) present and discuss these principles in detail. The principles can serve as guidelines for people involved in astronomy education and public outreach who are considering the use of VR.

In conclusion, this study contributes two significant elements to the field of VR in astronomy education, namely empirical and methodological insights. Empirically, the research focuses on the views of astronomy EPO professionals, offering a nuanced understanding of the challenges and opportunities that VR presents for astronomy education. Methodologically, the study champions the idea of reflective practice, involving researchers and practitioners in dialogues that integrate perspectives from design, astronomy, and educational research. This collaborative approach has led to richer dialogues and a comprehensive exploration of how content, pedagogy, and technology intersect in VR-based education.

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Massive Open Online Classes are an Effective Way to Engage Large Audiences of Adult Learners

Speaker: Chris Impey, University of Arizona, USA

Collaborators: Matthew Wenger, University of Arizona

Massive open online classes, or MOOCs, are intended for adult, lifelong learners worldwide. The author has created four astronomy MOOCs that have reached nearly 400,000 people in 180 countries. The core of a MOOC is a set of video lectures and other pedagogy that is effective in a MOOC, which includes citizen science projects, peer writing assignments, live Q&A sessions, and the use of social media and discussion boards. Completion rates of MOOCs can be low since free-choice learners often have jobs, families, and busy lives. However, when the learners complete surveys, do writing assignments, work on a project, or participate in discussion forums, the completion rate increases dramatically. MOOCs can reach audiences in developing countries that other modes of communication might not.



Talk link: <https://youtu.be/L1quea4an00>

MOOCs as Free Choice Learning Environments

Massive Open Online Courses (MOOCs) are classes aimed at unlimited participation and are free and open to anyone in the world who has access to a computer and the internet. MOOCs are part of a growing educational industry with a large buy-in from a growing number of universities (Friedman, 2013). Our group has been offering astronomy MOOCs since 2014 (Impey et al., 2015, 2016): two are on general astronomy, one is on astrobiology, and one is on the history and philosophy of astronomy. Three are offered by Coursera and one by Udemy. MOOCs offer an effective way to reach informal learners worldwide and give them a taste of state-of-the-art research in one of the most rapidly moving fields in science.

MOOCs are of interest to researchers because they are yet another out-of-school learning environment where people learn science, particularly adult learners (Falk & Dierking, 2010; Falk & Needham, 2013). Although MOOCs resemble formal classes (e.g., videos of content, quizzes, activities), the learning is more like that of a free-choice learning environment, which Falk and Dierking (2002) describe as “self-directed, voluntary, and guided by individual needs and interests.” In addition, they are more likely to be utilized by learners in informal contexts (e.g., from home), who are engaging with them as lifelong learning opportunities rather than as compulsory activities for formal credit or as a way to advance their careers. Recently, MOOCs

have been adopted by universities to conduct outreach, as they explore how to use MOOCs to reach more potential non-traditional students. Across the board, the completion rate among those who sign up for MOOCs is quite low, around 6% (Jordan, 2014). Despite the rapid adoption of MOOCs, research on individuals who take MOOCs is still developing as is our understanding of how learners interact with the course materials and what motivates them to finish the course.

Astronomy MOOCs present a special case of these courses in which students are often characterized as either “career builders or education seekers” (Zhenghao et al., 2015). Career builders take MOOCs to gain knowledge and skills that will help them find a new job or excel in their current work. Education seekers are looking for knowledge based on their own interests. A recent survey of nearly 52,000 learners who completed Coursera courses revealed that 52% of those learners enrolled in MOOCs were “career builders” and only 28% were “education seekers” (Zhenghao et al., 2015). This introductory astronomy MOOC resembles a lecture series more than an undergraduate course. We predict our students are more likely to be motivated to learn more about astronomy rather than to gain skills useful for a job.

Differences Between Informal and Formal Learners

Some of the observed differences between college students and MOOC learners can be ascribed to the different demographics and motivations for studying science in the two populations. Self-efficacy and self-motivation are the main reasons MOOC learners take the course; those motivations decrease with age but increase with the number of science courses they had previously taken (Formanek et al., 2019). This is a big contrast with college students taking a General Education course, who are fulfilling a science requirement and who often have no previous interest in astronomy or science in general.

The word counts of responses to “What does it mean to study something scientifically?” for college students and MOOC learners show that non-scientists are rooted in simple archetypes of the scientific method. The top dozen words per response in both groups have word counts over 500. Attributes that scientists most strongly associate with science, like “evidence” “experiment” “hypothesis” and “theory,” occur over 200 times for college students and over 700 for MOOC learners. Creativity is very strongly associated with science by half of the scientists, but “creative” or “creativity” only features in four college responses and 20 MOOC responses. Innovation and imagination are strongly or very strongly associated with science by over 2/3 of the scientists, but those words and their related stem words combined are only mentioned by seven college students and 28 MOOC learners. The word intuitive is strongly or very strongly associated with science by over half of the scientists but is only mentioned by one college student and 16 MOOC learners. Yet there’s abundant evidence that these four attributes are central to science (Chandrasekhar, 1987; Goodenough, 1993; Beveridge, 2004; Stuart, 2019).

While more work remains to be done to sharpen measures of how well non-scientists understand the process and basic results of science, the significant results from this study can be summarized as follows. Adults in an online astronomy class outperform non-science college freshmen and sophomores on a science literacy test, and they score slightly higher than a national sample of adults with advanced degrees from studies by the NSF. Adult online learners give longer answers than college students to open-ended questions about science, and in both populations, the length of the answers is correlated with science literacy scores. Adult online learners displayed more awareness than college students that DNA codes for information, while college students more often invoked incorrect and generic descriptions of DNA. The college students more often

gave answers that showed they thought radiation was harmful or dangerous. Adult online learners more often showed that they understood the role of software as instructions or code and the distinction between software and hardware.

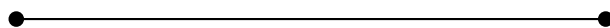
Compared with a set of professional scientists answering a question about the scientific method, both student groups were less likely to use many words that scientists most often invoke, such as conclusion, prediction, and control. The disconnect between scientists' descriptions of DNA and those of the two student groups was substantial. They agreed that DNA was genetic material but otherwise, there was little overlap. Adult online learners showed more positive attitudes towards science and technology and lower levels of belief in superstition and pseudoscience than college students. This is consistent with their higher education level and their inclination towards science as free-choice learners. College students show stronger faith-based beliefs than online astronomy learners, and for both groups, higher science literacy and more frequent use of words that scientists use to describe their activity correspond to weaker faith-based beliefs. Scientists convey a nuanced view of the process of science, strongly attributing the words creative, innovation, imagination, and intuition to doing science, while those words were rarely mentioned by the non-science students we've surveyed.

MOOCs, which are intended for informal adult learning, are exerting a disruptive force in higher education (Jones & Sharma, 2019). The trend toward online education triggered by the COVID-19 pandemic will increase the number of people taking advantage of the MOOC experience. In a modern world driven by science and technology, it is important to measure the knowledge and attitudes of lifelong learners. Science literacy has a meaningful, albeit small, effect on how people make decisions in their public and private lives (Allum et al., 2008). However, knowledge alone does not guarantee the adoption of a policy position driven by scientific consensus (Kahan et al., 2012; Pew Research Center, 2019). That is why we have balanced knowledge measurement with an analysis to probe how non-scientists understand the process of science. According to a recent survey of AAAS members by the Pew Research Center, the fact that the public does not know much about science is considered to be a major problem by 84% of the survey participants (Pew Research Center, 2015). As society wrestles with profound challenges, where the remedies will often involve science and technology, those involved in education and outreach must redouble their efforts to increase public understanding and appreciation of science.

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Window to the Stars: A Graphical User Interface with the TWIN Stellar Evolution Code for Students

Speaker: Andy Brittain, Lady Eleanor Holles School, UK

Window to the Stars (WTTS) provides a graphical user interface (GUI) to the TWIN stellar evolution code originally written for professional astrophysicists by Peter Eggleton. As Robert Izzard and Evert Gleebeck stated in their 2006 paper: “[WTTS] removes the drudgery associated with the traditional approach to running the code, while maintaining the power, output quality and flexibility a modern stellar evolutionist requires”. In fact, the GUI is user friendly enough for school children to use it, and that is precisely what is being done. Over the past few years, I have been collaborating with Robert Izzard, the GUI’s author, to establish a programme for school children that can extend and enrich their learning. This presentation discusses the application of WTTS to student-led stellar modelling projects.



Talk link: <https://youtu.be/2HIcNCP0czc>

Window to the Stars was developed to complement the TWIN single/binary stellar evolution code used by professional astrophysicists. The software acts like a web browser for stellar-evolution modelling. It is a graphical user interface that makes it easy to create stellar models. It provides users with the tools required to interpret these models, and helps them to understand the physics at work and make predictions about how stars will behave.

Several years ago, I met with Rob Izzard, who had developed WTTS at the University of Surrey in the UK. He had seen the potential of this software to enhance the science capital of secondary school students and, with that in mind, had developed a new outreach programme. I seized the opportunity and offered to trial the programme with several of my students, initiating a great synthesis of skills. My experience in the field, so to speak, meant that I was well placed to judge how the programme could be optimised for use in schools.

Firstly, we had to overcome the school network restrictions. We accomplished this by switching the software to a small standalone computer, the Raspberry Pi. This removed any interaction with school systems.

We also needed to adjust the documentation. I changed a few aspects of the conceptual flow, simplified some sections, and provided a bit more detail and imagery for others. I also added review questions that teachers could use to monitor student understanding and wrote a brief teachers’ guide.

We carried out several very successful trials with students at my school, including presenting our work at student conferences and to our local member of parliament. However, to progress this wonderful programme further, we needed to invite more schools to participate. I advertised the programme via teacher forums and received numerous expressions of interest from across the country. We then set up meetings with the Royal Society and negotiated the wording of a Partnership Grant that would provide schools with up to £3000 to fund their own WTTS project. My school also granted me regular day release to show other schools how to implement the programme. Over time, the programme has aroused interest from many institutions. The Royal Astronomical Society now promotes the programme in their output, as does UC Berkeley in America. Teachers from all over the world are now exploring its potential applications. I've personally received information requests from teachers working everywhere from India to Brazil. The Science and Technology Facilities Council in the UK has also recognised the huge benefits of this programme and provided a Research Grant to support its development at the University of Surrey.

Part I of the programme introduces the ideas of stellar astrophysics and computer modelling. Part II contains ideas and exercises to help students understand the astrophysics of stars and direct them towards independent project work.

When you first run the software, you encounter the Options tab. Here we can choose the initial conditions of the star, (i.e. its mass, M , and metallicity, Z), and change the physical prescriptions that are used when modelling the star. For the schools' programme, we only examine single stars, $M1$, although the software is designed for binary systems.

Once the initial parameters are set we can select the Evolve tab and start growing our star. In this window, we are presented with lots of code information for the experts to interpret. It could be a while before school students acquire the know-how to use this. During the evolution process, students can watch their star's pathway grow across a Hertzsprung-Russell Diagram, via the HRD Tab. The path lengthens as the student watches — the window expands to accommodate the path as required. The student can see the behaviour of the star as it progresses from its initial stable state to its departure from the main sequence and subsequent demise. The colours of the track are as close to a representation of the star as possible, but the user has extensive control over the presentation and labelling. It may, for example, be informative to include stellar age labels to understand how rapidly different stages progress.

The ρ - T tab shows the density and temperature track of the star. Students can observe this lengthening as the star evolves. The lines beyond which different elements fuel the star, are shown on a graph, and students can observe the changes in the stellar structure as the track intersects these points. For instance, when the track crosses the "He-burn" line, helium fusion starts, and the centre heats rapidly while at the same time its density drops.

The Structure tab allows you to make graphs of one property of the star vs another over its whole evolution or a portion of its evolution. There are an enormous number of parameter comparisons that can be made. There is one that correlates the radius of the star vs its age. We can see that towards the end of its life, a solar mass star will increase its volume tremendously.

Each star is iteratively evolved, with each model corresponding to a particular stellar age. The timestep length depends on the extent of parameter variations.

You can plot a huge selection of stellar properties at each timestep using the Internals tab.

In the case shown, the helium abundance by mass fraction, X_{He} , is plotted as a function of mass coordinate for every 100th model of a $1M_{\odot}$ model set. At the beginning (model 2), the star contains about 27% helium, while by model 1402, the core, from $0M_{\odot}$ to $0.47M_{\odot}$, is composed of 98% helium.

The Kippenhahn tab makes three-dimensional (3D) surface-colour plots of data. On the x and y axes, you can plot any structure variables such as time, model number, or mass coordinate, while on the colour axis (the z coordinate), you can choose any internal property of the star.

Here, we show the model number on the x-axis, mass coordinate M_r on the y-axis, and the colour is the logarithm of the temperature, so yellow is hot while blue and black are cold. You can see that up to just after model 200, during core hydrogen burning, the star hardly changes. After this, until about model 1200, the core heats while the envelope cools: the star gradually becomes a red giant. From model 1200 onwards, the star has a hot core and a very cool envelope until just after model 1400, when helium ignites in the core.

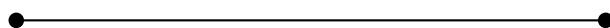
WTTS allows you to change the format of any of the images you generate, and it even has a “layer” option through which you can run multiple stars at once to compare their properties.

The programme documentation covers stellar spectroscopy, time scales in stellar physics (dynamical, thermal, and nuclear), computer modelling and Python, stellar structure and energy flow, astronomical distance measurements, cepheid variables, fusion processes, and star cluster dating. It even provides student research ideas such as exploring the impact of different hydrogen burning rates on life on Earth or producing a model of Barnard’s star.

In short, Window to the Stars is an absolutely marvelous piece of software. The programme is extensive and supports the steady development of expertise. It is perfect for use in schools and comes with the support of a network of experts in both Astrophysics, courtesy of Rob Izzard, and the school environment, courtesy of myself.

If you would like to find out more about the programme (either to offer your support or to use the software), please visit the website: https://stars_for_schools.gitlab.io.

Or you can email us at: starsforschoolswtts@gmail.com



LaSciL - Cutting-Edge Online Tools in Astronomy and Planetary Science for a (post) Pandemic World

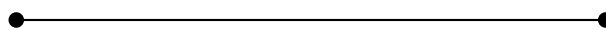
Speaker: Fraser Lewis, Dill Faulkes Educational Trust (DFET), UK

I will present results, conclusions, and evaluation from the recently completed (June 2023) Erasmus + program, LaSciL (lascil.eu; Large Scientific Infrastructures enriching online and digital Learning). LaSciL comprised five institutions from four countries to develop and support high quality science teaching during and after the pandemic. The partners created 29 PDF guides as cutting-edge educational tools, which have a significant online and/or digital component. 20 educational scenarios ('demonstrators') were developed in astronomy and planetary science. These are lesson plans which teachers can then copy or adapt to their own needs. Teachers also took part in 2-week-long 'summer schools' in which they created their own scenarios (another 48 of them) that they implemented in their classrooms.



Talk link: <https://youtu.be/WEOUmUN1UMY>

LaSciL brought together five institutions from four countries (Austria, Greece, Portugal, and the UK) to develop and support high quality science teaching during and after the pandemic. The project aimed to address the increasingly prevalent access to 'big data' as seen in modern science, especially astronomy. Examples here might include ESA's Gaia Mission, the James Webb Space Telescope (NASA, CSA, ESA), as well as the radio facility, the Square Kilometre Array (SKA), and the forthcoming Rubin Observatory, located on Cerro Pachon, Chile.



Pluto is Lost!

Speaker: Ekaterini Maria Rozi, Geology Educator - Science Laboratory
Administrator, Greece

It may be unusual to combine arts and drama with science, and its difficult terminologies are hard to transmit to the recipients through traditional teaching methods. However, the present paper describes our experience of science theatre addressed to the children of the 3rd Junior Highschool of Glyfada in Athens, Greece, with the main purpose of familiarising them with the Solar System, a topic largely underestimated in compulsory school curricula in Greece. A no less important task was to open our traditional classrooms, develop cooperative skills, achieve a common goal, and instill in students an intensive interest in what happens not only inside but also outside the classroom, where young people have to deal with societal problems while also seeking to create new ideas promoting research and innovation.



Talk link: <https://youtu.be/h3DTelQtOSI>

Learning Science Through Theater is an initiative of Science View, based on various European projects such as CREAT-IT, CREATIONS, OSOS, and CASE in cooperation with the Faculty of Philosophy, Pedagogy, and Psychology of National and Kapodistrian University of Athens and is under the auspices of the Greek Ministry of Education. The main purpose of the activity is for students to implement a theatrical performance related to scientific issues and thereby learn science in a creative way. The specific objectives of the activity, which have as a central axis the interdisciplinary interconnection of science with aspects of art, aiming at the enhancement of students' interest in science, involve both students and teachers.

More specifically, through this activity, students comprehend scientific concepts and phenomena, develop a spirit of cooperation and teamwork, actively participate in the discussion of scientific concepts, and develop creative and critical thinking skills. Teachers are engaged in professional development procedures through their cooperation in the project, and they gain an opportunity to exchange opinions, ideas, and teaching materials (either in person or through online learning communities). Finally, one of the main aims of the activity is to motivate more and more teachers and students as well as to create an educational community that will cooperate, exchange opinions, materials, and best practices for science teaching and learning, to continue after the implementation of the action.

The Junior High School for students aged 12 to 14 is situated in Glyfada, a suburb of Athens in Greece. Our school has a long history of science education; we have an active science laboratory

continuously running experiments, we participate in various activities seeking to enhance students' interest in science, and we participate in teacher training programs across Europe (CERN, ESA). We consider our school a "living" laboratory, a dynamic organization constantly interacting with the community, listening to the messages of our time, and responding to modern challenges!

Hoping to stimulate students' curiosity on a severely underappreciated topic of formal education while bearing in mind that it is impossible to visualize the Solar System on stage, we have written a script mainly relying on our imagination. Based on ancient Greek mythology, we "humanized-deified" the planets so they could be examined as witnesses by Halley's Detective – a Comet. Halley's Detective was hired by the Sun-Star-King when Pluto, furious about being expelled from the planetary group, the "hard core" of the Solar System, and having fallen into the new category of "dwarf planets," left with his moon Charon, disturbing the system's harmony (opening scene).

Halley's Comet starts his investigation from Mercury and ends up at Neptune, examining the planets and their main moons. As the planets are separated into rocky and gas giants by the asteroid belt, his search is interrupted by the dance of asteroids, the fear and terror of the solar system! Finally, Pluto is brought back to its place in the solar order by his mother-in-law, the dwarf planet Demeter – Ceres (in ancient Greek mythology, Pluto is married to Persephone, daughter of Demeter).

Students developed research questions, identified, investigated, and experimented on this scenario, constructing knowledge in the process. They selected the topic of the theatrical play, got immersed in active investigations of scientific issues, and engaged in collaborative discourse and creation. As a result, students managed to constructively build on each other's ideas, enhance their learning of scientific concepts, co-create, and perform theatrical plays. The co-creation engaged them in meaningful activities in authentic environments, while the theatrical performance helped them learn and express scientific concepts using their body, gestures, etc. Such embodied learning led students to the most successful representation of scientific concepts and enabled them to connect with modern forms of art. Even the unconscious movements performed by the students could be perceived as indicative of the degree of appropriation and embodiment of scientific concepts. They seem to have been able to understand the key features of each notion, using scientific terminology and simple vocabulary at the same time, to reliably describe notions and to use their past experience to describe scientific knowledge. Additionally, successful rendering of meaning was also possible both through verbal and non-verbal communication.

The meaning to viewers is conveyed with the use of **multiple representational systems**. In addition, we referred to the **modern challenges** we are called to face.

Honors and awards. *Pluto is lost* was awarded the:

- Best theatrical and musical performance related to scientific issues in the educational activity "Learning Science Through Theater" Athens, Apr 2017
- EPI2 2018 Science Communication Award in the category Best Fine and Performing Arts Project Approaching Scientific Issues From an Artistic Perspective. The award was issued by The Athens Science Festival organized by Science Communication–SciCo, the British Council, the Onassis Scholars' Association, and the General Secretariat for Research and Technology, in collaboration with various academic, research, and educational institutes,

Apr 2018

The best award though has been our students who didn't have the best marks, didn't like science but their performance has changed. They are looking forward to the new script every year. Isn't this the ultimate goal for us teachers? For our students to love science? How else can they go on studying hard for so many years if they don't have the passion for it? And believe me, they are growing more and more passionate!

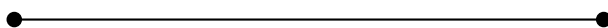
Combining Astronomy with theatre was a difficult task to accomplish. We could not rely on special effects to capture the audience's attention as the movies do. Nevertheless, the aims of the activity were met both for students as well as teachers. We have been using theatre to teach science since 2016, and we highly recommend it to the educational community, especially the activity Learning Science Through Theatre Urania, the muse of Astronomy, which was our first inspiration. Others followed, leading our students to science as well as to the formation of a star-observation group, an e-Twinning group, involved in light pollution. We will talk about this at the next Shaw-IAU workshop if our proposal is accepted.

We would like to thank the teams of *Learning Science Through Theatre* and *Science View*, especially Mr Menelaos Sotiriou, Prof Zacharoula Smirneou, Mr Spiros Citsinelis, and Mr Petros Stergiopoulos (for his valuable advice on music). Last but not least, we would like to thank the parents of our students and our colleagues at the 3rd Gymnasio of Glyfada for their help and constant support!

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Interdisciplinary Approach for Teaching School Level Astronomy

Speaker: Loraien Raju Kalathil, International School of Photonics, Cochin
University of Science and Technology, Kerala, India

Collaborators: Asmita Redij, Homi Bhabha Centre for Science Education (HBCSE-TIFR), V. N. Purav Marg, Mankhurd, Mumbai, India

This study uses a pedagogical framework that eliminates the subject boundaries and introduces a cohesive interdisciplinary teaching approach to teach subjects like astronomy, which is inherently interdisciplinary. Focusing on the topic of seasons, which involves aspects of geometry, science, geography, arts, etc., this work demonstrates the benefits of cross-subject integration. It delves into the process of finding the apt school-level topic for study, making concept maps about the topic, and using it for designing an interdisciplinary lesson plan for synchronized implementation by teachers. It will also address the pros and potential challenges during the implementation.



Talk link: <https://youtu.be/sFAHtz0xcaI>





Figure 1: Concept map of Seasons.

Traditional education often compartmentalizes subjects, hindering interdisciplinary learning. To prepare students for a multidisciplinary world, integrated teaching methods are crucial. This approach aims to merge knowledge from various academic domains, fostering holistic thinking and interconnected understanding [1]. In this approach, teachers are expected to highlight overlaps between subjects, encouraging students to see education as a part of a larger knowledge framework, rather than a set of isolated entities.

This project focuses on infusing interdisciplinary perspectives into astronomy education. Starting with the selection of topics from grade 5 to 8 Maharashtra State Board textbooks, we chose “seasons” from the grade 7 geography textbook. Beyond its inherent interdisciplinary nature, the chosen topic serves as a foundation for broadening discussions beyond their initial boundaries. Understanding seasons naturally leads to addressing the contemporary and critical issue of climate change. Investigating how shifts in climatic patterns impact the length and intensity of seasons involves a comprehensive examination of geographical changes, scientific explanations, and mathematical predictions. We employed a visual tool known as concept mapping to illustrate the complex relationships between ideas and concepts [2]. It is a useful technique for demonstrating how different elements within an interdisciplinary framework are interconnected.

The concepts of integers and 3D shapes have already been covered in the grade 6 mathematics curriculum of the Maharashtra State Board. To revisit these previously covered topics, teachers may utilize problem-solving activities. Additionally, for geometry lessons, a hands-on approach can be employed through craft classes, allowing students to physically create 3D objects, thereby enhancing their comprehension.

Furthermore, it is feasible for teachers to revisit various subjects that students have encountered in earlier grades using similar interactive methods. For instance, the geography teacher can

Subject wise distribution - The lesson plan

LEGENDS	Mathematics	Geography	Physics
1. Revisit Integers - problem-solving activities	2. Revisit 2D and 3D solid shapes - making models using old cardboard or using interactive online tools.	3. Geometrical construction of 2D and 3D shapes.	
4. Geometry of celestial bodies like Earth, Sun - Emphasize on the Earth's tilted axis.	5. Motion, force and work - Distance, displacement, velocity, force and its unit, gravitational force.	6. Angles and pairs of angles - can be explained using doors.	
7. Geometry of an ellipse - Using interactive online tools.	8. Earth's revolution in elliptical orbits and the revolution and rotation of the Earth, and its effects- Visualization using "Earth Space Lab".	9. Introduction to cartesian geometry - Using "desmos". Introduction to spherical geometry - an orange/onion can be used to explain.	
10. Earth and its graticules , Understanding to draw graticules- Visualization using online tools.	11. Light and formation of shadows. Effects of light - eclipses. Visualization using "Earth Space Lab".	12. Heat and its various effects.	
13. Concept of differential heating , relating to seasons.	14. Core concept of seasons , emphasizing the interconnectedness.	15. Impact of seasons - interactive discussions.	

integrate the principles of geometry concerning the Earth, the Sun, and its orbital dynamics, with particular emphasis on the Earth's axial tilt. To augment this learning experience, an online interactive session can be organized, enabling students to visually comprehend these celestial concepts.

This holistic approach can be extended to all the topics outlined in the curriculum. Geography teachers can collaborate with their mathematics counterparts to foster a comprehensive understanding of concepts such as the Earth's graticules by establishing a foundation in spherical geometry. It is imperative that educators underscore the interconnectedness of these diverse subjects, elucidating how mathematical principles underpin geographical phenomena.

In order to enhance student engagement, lesson planning should incorporate brief, stimulating activities and promote the utilization of computational tools to bolster the learning process. Additionally, scheduling activities should be aligned with the available class time to optimize the educational experience.

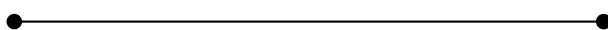
The implementation of interdisciplinary teaching in schools is constrained by various challenges. The emphasis on standardized tests can disincentivize educators from exploring innovative teaching approaches, including interdisciplinary methods. Teachers may lack the necessary training and confidence to teach various subjects, while standardized assessments are designed for subject-specific content [3]. Resistance from school administrators, a shortage of interdisciplinary teaching materials, and time constraints in class are additional hurdles. Collaboration among teachers from different disciplines can be hindered by communication barriers, such as differences in terminology and pedagogical approaches [3]. Furthermore, students may enter interdisciplinary courses with varying levels of preparedness, which makes it challenging to meet the needs of all learners. Overcoming these constraints requires a collaborative effort among educators, administrators, and policymakers to create a supportive environment for interdisciplinary teaching and provide the necessary resources and training for its successful implementation [3].

Acknowledgement

This work was supported by the National Initiative on Undergraduate Science (NIUS) undertaken by the Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research (HBCSE-TIFR), Mumbai, India. We acknowledge the support of the Department of Atomic Energy, Govt. of India, under Project Identification No. RTI4001.

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Connect with Stars : A Novel Attempt to Teach Constellations to Kids

Speaker: Atul Bhat, Poornaprajna College & Poornaprajna Amateur Astronomers' Club, India

In most current materials, constellations are depicted only through the brightest stars, with no background stars visible. Although there are materials that provide a proper picture of constellations against a starry background, they are often displayed upright with no information regarding their orientation, which changes over time. Spotting a constellation requires practice and knowledge of parameters like visibility, orientation, and also its position in the sky during various months. At Poornaprajna Amateur Astronomers' Club, we have compiled all of this information visually, making it easy for middle school and high school students to learn about individual constellations and make use of IAU-Sky and Telescope's Constellation Maps.



Talk link: <https://youtu.be/NDy3r8EvCWQ>

Introduction

"Twinkle, twinkle, little star, how I wonder what you are. . ." is often the first lesson most human beings have on astronomy. This nursery rhyme, also taught in India, sparks fascination about the composition of stars. However, astronomy, which began in people's minds with this basic rhyme, remains largely unexplored within the academic framework of Indian schools.

John Percy (1) highlighted the need for improving astronomy education in formal school curricula. In India, astronomy is introduced for the first time at the eighth-grade level, according to the CBSE syllabus, as part of Natural Phenomena class, focusing on the phases of the Moon and seasons. Unfortunately, these lessons seldom cover stars, the patterns they create in the night sky, constellations, zodiac constellations, or other fundamental aspects of amateur astronomy that students should be aware of.

Despite the lack of emphasis on astronomy in the school curriculum, most school-going students, including the very young, are naturally captivated by the stars and aspire to explore them further in the future. At the Poornaprajna Amateur Astronomers' Club (PAAC), continuous efforts are made to facilitate public engagement with astronomy in the most accessible manner possible. These efforts include activities, broadcasts, and visual aids, often shared through social media. One such initiative is "Connect With Stars".

Need for 'Connect with Stars'

Students are typically introduced to constellations and stars through tools like sky-maps and star-wheels, which assist in night sky observations. These materials can be broadly classified into two categories. The first category consists of charts and maps with intricate details and specific coordinates, requiring observers to possess knowledge of astronomy nuances and a pre-existing motivation to use such resources. In contrast, the second category includes introductory materials that mention constellations and their patterns but predominantly highlight the brightest stars in the area. Even the detailed plates in Urania's Mirror primarily emphasize bright stars but lack guidance on where and how to locate a specific constellation (2).

Guides and books that explain the Big Dipper constellation do mention how to spot the constellation using the horizon and the pole star but make no mention of nearby stars or constellations. (3)

'Connect with Stars' : The Teaching Aid Design

Most of us have come across the puzzle that is commonly known as 'Connect the Dots' or 'Dot-to-dot'. From the evolution of the Columbus Eggs, proposed by Sam Loyd in 1907 (4), the puzzle evolved from connecting mere dots in the Birmingham Age-Herald (5) to connecting dots that are numbered, as was published in the Newark Evening Star (6). Afterwards, many newspapers and periodicals published such puzzles to engage their audiences with activities.

The dot-to-dot puzzle was also incorporated in the Reuven Feuerstein's cognitive enrichment program to help assess kids from kindergarten to 3rd grade (7). Studies have also shown that the program was efficient in the cognitive functioning, coupled with the educational curriculum. (8)

What if students could apply the skill of connecting the dots to linking the stars in constellations? Unlike typical dot-to-dot puzzles that avoid nodes and line intersections, connecting the four stars of 'Cruce' would require intersecting lines. To address this challenge, individual 'connections' can be introduced, where two stars are linked by a line. This approach allows the constellations to take shape without concern for intersections, making it easier to view and understand the constellation.

To prevent the conventions commonly found in books that depict only the brightest stars within a constellation and omit nearby stars, a precise map of the night sky was needed. This map had to strike a balance between complexity and simplicity, providing both clarity and comprehensive information.

Roger Sinnott and Rick Fienberg produced constellation maps in collaboration with the IAU under the CC BY 4.0 license for the Sky & Telescope magazine. (9) Constellation maps were based on Alan MacRobert's patterns, which in turn were based on H.A. Rey's designs. (10). These maps offer an advantage over other designs or the option of creating our own because they represent stars as dots of varying sizes, reflecting their magnitudes. This intuitive design aids students in understanding that larger dots represent brighter stars while smaller dots indicate dimmer ones. This allows students to visualize the entire constellation, including all the stars in the star field, and estimate which stars are easier to spot. Additionally, the maps include Bayer designations for stars, which can be used to specify connections and educate students about the Bayer designation system.

For younger students, a faint overlaid image of the constellation, or a “picture,” is included to provide guidance.

With the foundational map in place, a connections table can be specified, linking pairs of Greek alphabets to form the constellation lines. Additionally, information about nearby constellations and star density can aid in identifying the location of the constellation in the sky. Furthermore, providing brief details about the constellation, the significance of its historical spotting, and the associated mythologies can enhance students’ knowledge about the specific constellation.

When the constellation image is generated, it can be challenging to randomly locate the constellation in the night sky, especially without knowing its visibility during specific months. Furthermore, constellations change orientation over time, rendering the specified orientation on the map inaccurate.

To address this, a new section was added at the bottom of the map dedicated to spotting the constellation and its orientation. This section specifies the part of the sky where the constellation will be visible and provides guidance on how one can align it with the north-needle on the map to discover the constellation’s orientation during the month. Additionally, other relevant information such as attribution and a legend for deep sky objects would be retained to provide further context and detail.

Expected Outcomes

The realized ‘puzzle-sheet’ is a resource that contains essential information about a specific constellation. This includes details about the stars that comprise the constellation, the stars needed to identify it, the part of the night sky where it can be seen, and its orientation. This resource also provides insights into the constellation’s mythology and presents its name in the local language, rendering it a valuable educational tool for students.

The design of this ‘puzzle-sheet’ is particularly geared towards younger students, using gamification to help them learn about constellations and the stars within them. It aids in identifying and spotting the constellation in the night sky, even specifying nearby stars for reference. However, it’s worth noting that younger students may require some guidance with it since the position and orientation guides can be challenging for students in lower grade levels to understand.

Conclusion

The activity to connect the stars allows students to engage with the stars of a particular constellation and is therefore named ‘Connect with Stars’. Like dot-to-dot, this puzzle holds the potential of allowing students to learn constellations factually, visually, and also through a cognitive perspective. PAAC, through the authors of the design, expects to carry out further research so as to identify the most suitable audience and effectiveness of the illustration and information along with other markers. However, in the meantime, the puzzle serves as an initiative that helps adults spot constellations, allows children to engage in an activity related to astronomy, and both to learn about constellations.

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STEM+A@Astronomy: Integrate Art in Astronomy Education Through Low-Cost STEAM Activities

Speaker: Exodus Chun-Long Sit, Starrix, Hong Kong

Teaching astronomy, an interdisciplinary natural science, has emerged as a new feature in formal education within schools and at public science communication events. However, given the sizeable target audience, it might lead to concerns regarding how to minimize operational costs and expenditures. The talk will introduce an interdisciplinary project called STEM+A@Astronomy. It aims to cultivate learners' curiosity and hands-on skills through low-cost STEAM activities. It could link up to different aspects in science lessons for students and interactive activities for the public, including space science, astronomical observation, dark sky protection, and planetary science about our solar system.



Talk link: <https://youtu.be/SGZtdJiFq7c>

The STEM+A@Astronomy project is an interdisciplinary project which aims to promote popular science and dark-sky awareness of urban light pollution through experiential learning. In recent



Figure 1: Bioluminescence and fluorescence of colorful creatures under dark sky environment.

years, STEAM approaches (Science, Technology, Engineering, Arts, and Mathematics) have been recognized as crucial elements in science education. We have further modified this idea and applied it to astronomy education and science communication within the new “STEAM”.

It began with Sustainability (abbreviated with an S), which is also a part of the United Nations’ 17 sustainability development goals (UNSDGs). UNSDGs are crucial parameters to be considered when designing lesson goals and expected learning outcomes. In the interactive classroom, our goal is for students to acquire 21st-century skills and be equipped with abilities they will need in the future. This includes developing sustainability and systems thinking to devise environmentally friendly strategies and address future challenges. We aim to prepare students to react effectively to unexpected changes and paradigm shifts.

Concerning Technology (abbreviated with a T), the younger generations can participate in different citizen science projects by using simple digital devices and the internet. Learners can get access to free learning resources and manuals when contributing as citizen scientists. Besides that, there are also some useful educational software and educational technology products (EdTech), including holographic projection of astronomical objects (for visualization and demonstration) and game-based space software in online learning platforms.

The Arts (abbreviated with an A) are another aspect to consider, which includes space art and Astro-music. Both are good mediums to motivate learners to explore the resonance and uniqueness of astronomy. For example, “Planets in Circular Scores” (Fig.2) is a graphical score designed by Exodus Chun-Long Sit. It transformed the distance of planets in our solar system into the circular score (Fig. 3) and recreated the traditional musical score into a minimalist line score. Besides, there are also Astro-Music compositions (Fig. 4), such as “The Melody of Planetary Motions” and “The Harmony of Mysterious Exoplanets,” which motivate learners to explore Astronomy in different ways.

The final aspect to consider is Materials (abbreviated with an M). There are lots of different recycled materials that we can see in our daily lives. We can use plastic bottles, cardboard, and aluminum foils to build prototypes of DIY Light-Up Constellations and DIY Dark-Sky Friendly Light Shields to promote popular science. We can also use paper to make astronomical 3D models, including rocket models and pinhole boxes for solar eclipse observation. Of course, there are many interesting ways for students to explore different angles and creative parts of astronomy education, which can nurture future generations. With this in mind, we hope to save our night sky and preserve our ancient mythology and cultural heritage of celestial objects and

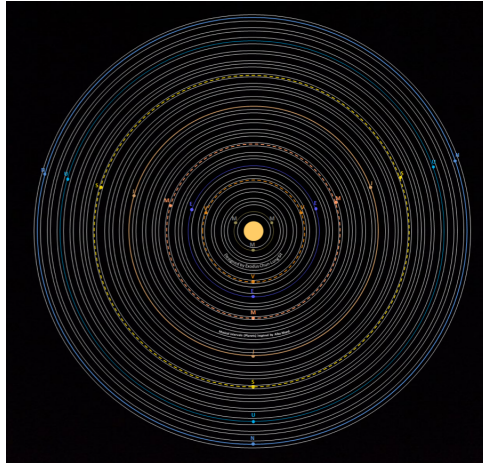


Figure 2: “Planets in Circular Scores” By Exodus CL Sit.

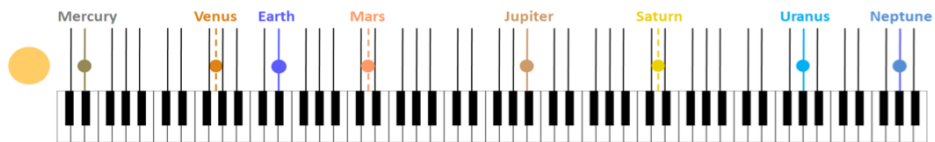
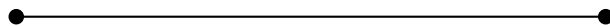


Figure 3: The musical notes of each planet in our Solar System on piano keyboard.



Figure 4: Astro-Music Public Lecture of SciFest 2023 in Hong Kong Space Museum.

constellations.



Inspiring Astronomy Education: Fostering STEM Interest Through Meteor Studies

Speaker: Stijn Calders, Royal Belgian Institute for Space Aeronomy (BIRA-IASB), Belgium

Collaborators: Hervé Lamy (Royal Belgian Institute for Space Aeronomy), Mieke Sterken (International Polar Foundation), Karolien Lefever (Royal Belgian Institute for Space Aeronomy), Katrien Kolenberg (KU Leuven, Antwerp University, and VUB), Michel AnCIAUX (Royal Belgian Institute for Space Aeronomy), and Hans Coeckelberghs (Planetarium of the Royal Observatory of Belgium)

MOMSTER (MOBILE Meteor STation for Education & outReach, <https://momster.aeronomie.be/>) crafted a Meteor Education Kit for secondary school STEAM teachers. This kit features a mobile radio meteor station with an antenna and a receiver, accompanied by an educational package. It explores meteors' impact on Earth and the atmosphere, evoking fascination with their beauty. Goals encompass inspiring STEAM pathways, integrating citizen science (notably Radio Meteor Zoo on Zooniverse), and broadening public outreach. The initiative secured a Europlanet grant in 2020.



Talk link: <https://youtu.be/19MZxp-fW9c>

MOMSTER (MOBILE Meteor STation for Education & outReach) has developed a Meteor Education Kit as a resource for STEAM (Science, Technology, Engineering, Arts, Mathematics) teachers in secondary schools. This kit includes a mobile radio meteor station consisting of a dedicated antenna and radio receiver, as well as an educational package to learn all about meteors and their impact on the atmosphere and the planet as a whole. Simultaneously, it aims to convey a fascination for the ephemeral beauty and complexity of these natural light shows.

Bringing the device to schools provides a unique opportunity to reach out to youngsters who might not have such opportunities otherwise. This includes children with disabilities or those from underprivileged families, regardless of gender. The artistic aspect may also attract students with varied interests. Our concept's design increases the potential to connect with those who are often overlooked.

Project goals

The project goals are threefold: promoting STEAM, stimulating the use of citizen science in schools, and reaching the general public.



Figure 1: A student setting up the MOMSTER antenna.

1. Promoting STEAM: Through this project, we're using meteor science and observations to spark the curiosity of teachers and high school students in STEAM activities. This initiative aims to guide them towards potential careers in science or engineering. Radio meteor observations, especially during the day, are a great way to achieve this goal because they align with school STEAM curricula seamlessly.

2. Stimulating the use of citizen science in schools: We encourage teachers and secondary school students to participate in the Radio Meteor Zoo (<http://www.radiometeorzoo.org>), our Citizen Science project aimed at detecting radio meteor echoes on BRAMS spectrograms during meteor showers.

3. Reaching the general public: By strengthening our BRAMS network and creating and utilizing educational resources, we attract more attention from teachers, parents, as well as the local press. The strong educational component of this project will consolidate the collaborative relationships between BIRA and visitor centers, creating additional momentum for the general public to start participating in the Radio Meteor Zoo citizen science project.

Educational material

Space and atmospheric science are STEM disciplines par excellence, involving various fields of science (physics, mathematics, chemistry, biology, geography, engineering, ...). As a subject triggering the imagination, the "study of shooting stars and meteor showers" has the potential to raise interest in STEM disciplines and enhance the retention of scientific information by integrating with art and citizen science, both in formal and informal education settings. The following educational resources are available in Dutch and French on the MOMSTER website (<https://momster.aeronomie.be>):

- Geography: the relationship between comets and meteors
- Arts: infographics and science-based art
- Mathematics: calculation of distances using Pythagoras' theorem and geometry used to retrieve the meteoroid's path

More teaching materials are currently under development, especially about geography (meteorites in Antarctica) and physics (diurnal variation of meteor activity).

Acknowledgment

In 2020, this project received a grant from the Europlanet public engagement funding scheme.



Figure 2: In 2021, we organized an art contest. The winning design, made by a student called A. Van Poppel, now decorates the MOMSTER box.



Astronomy Education by Pursuing Specific Projects for Students in a Planetarium Setup

Speaker: Jayant Ganguly, Regional Science Centre and Planetarium Calicut, India

By undertaking one's own research project, students are expected to extend their exposure to topics covered in their curriculum. They should recognize the importance of data collection through various experimental setups, data analysis, and visualization and representation methods adopted in their fields of study. Over the years, RSCP, Calicut, has designed and developed experimental setups that college students can utilize to gather data, analyze it, and draw concrete conclusions. Through this process, they can train themselves in experimental methods in astronomy. In this presentation, we aim to demonstrate how these inexpensive yet rigorous experimental techniques fulfil the basic objective of astronomy teaching in college education.



Talk link: <https://youtu.be/72QTshH5MEw>

Imaging celestial objects and using image analysis software to undertake specific measurements, conduct error analysis, prepare a project report, and present the topic of study to a scholarly

audience was the goal of the project. Some of the projects elucidated in this paper are: measuring the height of lunar mountains and crater depth, measuring the outer and inner ring of Eskimo nebula, and examining the dynamics of sunspots.

Some students were encouraged to take up projects related to instrumentation in astronomy, such as “Construction of Jove Receiver” and “Studies of the Sun.” Furthermore, some students were trained in citizen science-centric data analysis projects, such as “Studies on the Climatic Patterns of Mars,” whereas other students conducted theoretical analyses of astronomical concepts.



Figure 1: Processed image for measuring the height of Mount Pico.

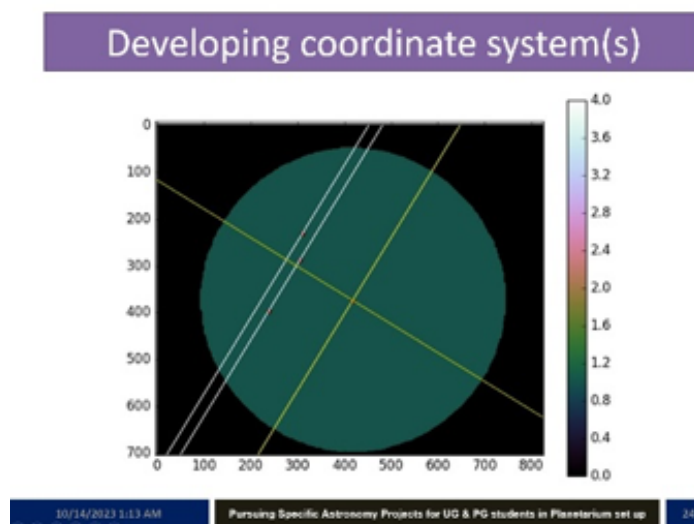


Figure 2: Coordinate system for locating sunspots.

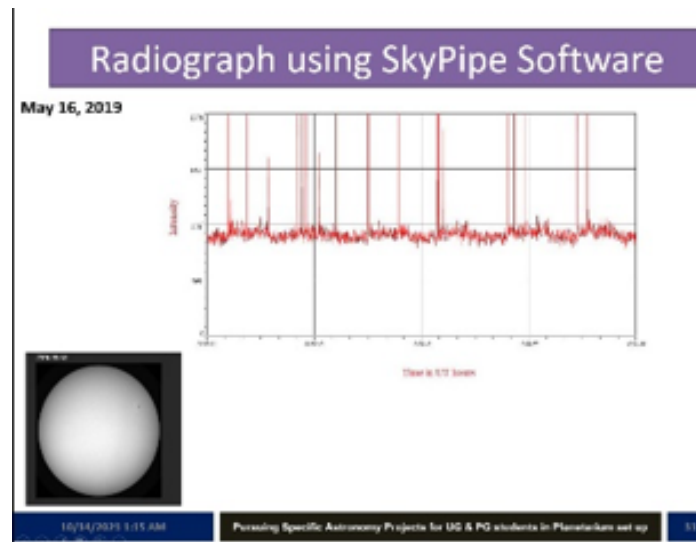
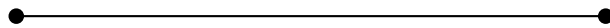


Figure 3: Radiograph of Sun on May 16, 2019 using Radio Jove.

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Can AI Help Us Better Prepare Students for Their Future?

Speaker: Rosa Doran, NUCLIO - Núcleo Interativo de Astronomia e Inovação em Educação, Portugal

Artificial Intelligence is now trending all over the internet, and new solutions and possibilities appear every day. Should educators explore this new technology or find ways to prevent their students from using it? Can we integrate AI to enrich our lessons? Is it okay to use AI to assist us in preparing personalised and differentiated lessons? Will AI endanger or enrich students' learning experiences? During this session, I intend to share a few views on this and invite the audience to also share their views.



Talk link: https://youtu.be/000F__y4aAA

Artificial Intelligence is increasingly invading our lives, and discussions about its integration into schools or the world of work are becoming ever more relevant. It is important to understand its capabilities and effectively integrate them into our current practices. The first step is to recognize that AI inhabits our everyday life, such as through face recognition on smartphones, navigation systems to assist us in reaching our destinations, personalised offers on social media, grammar checking in our emails, etc. Its presence in our daily routines is, in fact, omnipresent. Like it or not, AI is here to stay, and the best approach is to understand it as thoroughly as possible and be aware of its dangers and limitations.

AI can help educators enhance students' learning experience, improve lessons' accessibility, provide real-time feedback, and help them create engaging materials. For example, students are taking advantage of tutoring systems such as "Khan Academy", improving their work by using apps such as "Grammarly," and deepening their research by using the help of Chat GPT to assist them in their research.

Students can, of course, use these facilities for wrong purposes, such as using them to complete their assignments. That is precisely why learning how to take advantage of AI systems will greatly help educators in their mission to reinvent education in the era of advanced support tools, aiming to improve students' learning experiences.

AI algorithms are not perfect, and we often encounter wrong information and incorrect references to papers or books. Therefore, critical thinking skills are becoming increasingly important. AI can be of great support for those who use it in a smart, conscious, and critical way.

Some projects, such as Design CT and Discovery Space, both funded by the European Union, are taking advantage of AI capabilities to support educators in the construction of learning scenarios and in the assessment of students' learning path.

In Design CT teachers will find a chat bot that will help them create summaries, questions, key points, and more.

Discovery Space provides educators with a learning environment where educational scenarios can incorporate conversational agents that will guide students towards the best path for their personal learning growth. AI will be integrated as a mechanism to enrich students' learning experience and to assist them in better understanding various concepts. Teachers will find in these projects a powerful and innovative way to assess their students and offer them a deeper learning experience.

So, in essence, AI can significantly improve the learning experience of students and simplify the workload of educators.

POSTER CONTRIBUTIONS

Using a Disco Ball to Observe the Sun - and Partial Solar Eclipses

Presenter: Robert Cumming, Onsala Space Observatory, Chalmers University of Technology, Sweden

Collaborators: Alex G. M. Pietrow, Leibniz-Institut für Astrophysik, Potsdam, Germany; Valerie Rapson, SUNY Oneonta, USA

Disco balls (mirror balls) provide a surprisingly safe and fun way of observing the Sun, particularly during partial solar eclipses. We provide an overview of their optics and their potential for use in education and outreach contexts.

Poster link: <https://doi.org/10.5281/zenodo.10443589>



Disco ball optics

A disco ball is a collection of pinhead mirrors, each functioning as a pinhole camera. Images of the Sun are projected in all directions. Near-field images, close to the ball, project the same square shape as the mirrors, while distant images fall within the near-field diffraction regime. The images become sharper at a larger distance but at the expense of brightness. Source brightness, screen contrast, and internal reflections limit image quality. The Moon is too faint to be observed under the conditions we've tested. Our test results indicate that sunspots are visible even with inexpensive disco balls, though only the largest sunspots can be seen. Partial solar eclipses are easy to observe with any disco ball.

Partial solar eclipses

How can disco balls complement other ways of observing solar eclipses? We want to provide guidelines for North American eclipse observers in April 2024, when millions of people will have the opportunity to experience a solar eclipse. We scheduled tests during the 14th October 2023 eclipse in collaboration with Valerie Rapson (SUNY Oneonta, USA) and others.



Figure 1: Disco ball images of the partial solar eclipse on 25 October 2022. (Credit: Alex Pietrow)

Tips and research questions

We recommend trying out a disco ball during your next solar eclipse. Our tips and research questions (in italics) are as follows:

1. Buy or borrow. Find a disco ball that you can use at your event. Any size and quality is good. *How easy is it to find a suitable ball?*
2. Test. Before the eclipse, test viewing the Sun with a disco ball at your chosen venue. What can you use as a screen? To see details, you will need a smooth white surface. *What is needed to get the location and mounting right?*
3. Show. During the eclipse, use the disco ball to show the event's different phases to visitors. *What safety precautions are needed? What practices work best for showing and explaining?*
4. Listen. During your event, talk to visitors about the solar images created by the disco ball. *How do people interact with the ball and its images? How do they talk about it with each other? What questions come up? How can you help people understand what they see?*
5. Share. After your event, please email us (Robert Cumming robert.cumming@chalmers.se, Alex Pietrow apietrow@aip.de). We want to collect feedback and prepare for future events. *How does the disco ball compare to other eclipse viewing equipment? What preparations are needed? What happens when the eclipse approaches totality?*

For more detail, see our paper Cumming et al. 2023, submitted to *Physics Education* (<https://arxiv.org/abs/2309.14173>).



Using Tolkien's Calendar as a Resource in Science Class

Presenter: Javier Vaquero-Martinez, Universidad de Extremadura, Cáceres, Spain

Tolkien's legendarium has been very popular in the last years, thanks to the Lord of the Rings and The Hobbit films, as well as the recent series The Rings of Power. It is well known that Tolkien was very thorough in creating this world, coming up with languages, maps, and even calendars for the different folks in Middle-Earth. In this contribution, we explore the use of Tolkien's calendar in science class, comparing it with our calendar. This can be used to further motivate students and increase their curiosity not only about how calendars work but also about the rules our current calendar follows and the reasons behind them, which are very much related to Astronomy and Earth Sciences. We demonstrate that Tolkien's calendar slightly outperforms our calendar despite its other drawbacks.



Poster link: <https://doi.org/10.5281/zenodo.10443611>

Tolkien's legendarium is now a part of our culture. Not only the books but especially the films directed by Peter Jackson and the new Series "The Rings of Power," produced by Amazon Prime Video, have been extremely popular in recent years. J.R.R. Tolkien not only wrote a series of fantasy books about Middle Earth, elves, dwarfs and hobbits but also endeavored to recreate every aspect of their existence: the geography of the places where they lived, their languages and alphabet, and even their mythology. Of course, the measurement of time was also not forgotten, providing us with a wonderful opportunity to learn about the science behind calendars.

Calendars are fundamental tools in a society for planning all sorts of activities, including agriculture with sowing and harvest times, among others. Moreover, societies rely on calendars to establish holiday dates and other important occasions. However, creating a calendar is a complex and difficult task. Without the technological means available today, such as clocks and already established and precise calendars, few of us would be able to determine the date, the duration of a year, and other important magnitudes to create an accurate calendar.

One of the main problems in the measurement of time is that it does not have a tangible magnitude. We can establish the standard for a meter or the standard for a kilogram, but how can we establish the standard for a second? Our ancestors realized that the best choice for a standard would be a periodic event. Of course, they used astronomical events because they realized they were periodic. Even today's calendar, despite having more precise ways of

measuring time, uses astronomical events to maintain periodicity. Calendars follow the Sun's apparent motion since it is the main driver of our lives (warm and cold seasons, day and night, and similar). Therefore, we can define the tropical year as the time the Sun takes to circle around to the same position in the sky, for instance, from winter solstice to winter solstice. The tropical year thus currently has a value of 365.242188 days.

Nowadays, the calendar used in most parts of the world is the Gregorian calendar, consisting of years with 365 days. However, every 4th year we have a leap year that has 366 days. This rule has one exception — every 100th year, the leap year is omitted. Again, this last rule has another exception — every 400th year, this omitted leap year is included again. With these rules in mind, it is easy to calculate the mean duration of a year in this calendar, which is 365.2425 days. This number is, however, different from the tropical calendar by 0.000312 days (about half a minute per year, resulting in a difference of 15 hours every 2000 years).

Going back to Tolkien's legendarium, he created different variations of the calendar for the different folks in Middle Earth. Of course, Elves, having very long lives, would use longer periods of time, while humans and hobbits used similar calendars. We will focus on the Hobbit calendar, as it is the one described in more detail in the Appendices of *The Lord of Rings*. Note that according to Tolkien, the duration of one year was 365 days, 5 hours, 48 minutes, and 46 seconds, which is the same as the tropical year in the real world. Therefore, we can assume that we are on the same Earth.

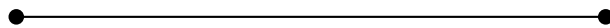
Tolkien also reproduced part of the evolution of our calendars when giving hobbits a calendar. In the beginning, when hobbits were nomads, they used months based on the lunar motion. This was a clear reference to the lunar calendar that the first human civilizations had. He also reproduced the different changes in the calendar, such as adjustments made by political powers to keep the correct track of time when needed, like adding or removing leap years.

Although the Hobbit calendar was similar in most respects to ours, it included some interesting novelties. The general structure has 12 months of 30 days each, and 5 days that were not of any month (these served as holidays and did not belong to any month). Moreover, they had weeks of seven days. However, Midyear's Day did not belong to any day of the week, resulting in exactly 52 weeks in every year. This arrangement ensured that each day of the year had the same day of the week every year. For example, the first day of the year was always a Saturday, and the last was always a Friday, which was very convenient as it eliminated the need to get a different wall calendar every year. The Hobbit calendar included leap years every 4th year, similar to ours, and kept the exception for the 100th year. Additionally, the first and last years in a millennium were also leap years. With these rules, the mean duration of a year was 365.2420 days, and the difference with the tropical year was approximately 0.000188 days (about 16 seconds per year, resulting in a difference of 9 hours every 2000 years).

It will be surprising for many students to find out that the Hobbit calendar is more precise than ours, so it is important that they consider its convenience. The period of the Hobbit calendar is 1000 years, while the Gregorian calendar has a period of only 400 years. This means that accumulated errors can be much higher for specific years, up to 1.88 days, in the case of the Hobbit calendar.

This examination of the Hobbit calendar can be very motivating for students. It can help them reflect on how we measure time, why we have years, and why it is important to keep the

calendar aligned with the astronomical events they represent, such as equinoxes and solstices. It can motivate students to learn more and encourage them to try creating their own calendars with increased precision compared to the Gregorian calendar, while also exploring potential drawbacks they might have.



Moon Observations for Age Groups 8 -12

Presenter: Shylaja B S, Jawaharlal Nehru Planetarium, High Grounds, Bengaluru, India

We always held 5-day or 10-day workshops on astronomy, starting two days after the new Moon. Therefore, observing the phases of the Moon was easy. However, the same idea was applied to note the moonrise and moonset timings. Later, this idea was extended throughout the year, leading to many interesting ideas for discussion. We would meet once a month to discuss and try to understand the relative motions of the Sun (Earth) and the Moon using tables of moonrise and moonset (as well as sunrise and sunset). This could be introduced as a special activity in the regular curriculum.



Poster link: <https://doi.org/10.5281/zenodo.10443602>

DISCUSSION SUMMARY

The speakers from the session took part in an active discussion with many questions from the audience. As this was a session on teaching methods and tools, many of the audience's questions were on how to access or replicate the tools that were presented.

In part 1 of the session, the speakers discussed a range of topics primarily related to the use of technology in the classroom. Rosa Doran discussed the use of AI in small ways to help reduce teachers' workloads and improve interaction with an AI to enhance its answers. Chris Impey talked about his use of AI to create a searchable library of voice-based answers and questions. The library allows users to find answers without the risk of the AI hallucinating an answer. Andy Brittain and Fraser Lewis addressed the challenges teachers face when trying to access databases and interfaces designed by and for professional astronomers.

In part 2 of the session, the discussions focused on the educational projects presented and how they could be implemented by others. Jayant Ganguly talked about how astronomy lab projects could be incorporated into the curriculum. Both Atul Bhat and Ekaterini Maria Rozi discussed how much guidance students need while still maintaining their creative freedom. Stijn Calders suggested ways teachers in other countries could use TV and radio broadcasts as sources when searching for radio reflections off of meteors. Finally, Loraien Raju Kalathil talked about plans to implement the project she presented in schools and how its impact will be evaluated.

WORKSHOP AND COMMUNITY DISCUSSIONS

astroEDU Workshop

Session organisers: Livia Giacomini (INAF Italy, OAE Center Italy), Giulio Mazzolo (astroEDU associate editor), Gwen Sanderson (OAE Heidelberg), Federica Duras (INAF Italy), and Edward Gomez (LCO, UK)

WORKSHOP SUMMARY

Executive summary

During the **5th Shaw-IAU Workshop on Astronomy for Education** (29 November-1 December 2023), the AstroEDU Editorial Board organized two sessions of an online workshop dedicated to the AstroEDU platform. Almost 300 participants accessed the sessions, interacting with the organisers with real-time polls and questions asked via chat. The workshop offered a valuable opportunity to share the educational and outreach capabilities of AstroEDU, and to analyze its target audience, thanks to the involvement of a dedicated University Master thesis.

Organisation of the AstroEDU sessions

Each of the two sessions of the workshop was conducted by more than one person: Livia Giacomini, Federica Duras and Edward Gomez for the first session (29 November 2023); Giulio Mazzolo and Gwen Sanderson for the second (1 December 2023).

Antonella Corleone — a student of Università degli Studi Roma Tre, currently undertaking a thesis focused on AstroEDU for a Master's degree in Mathematics (Educational Outreach) — participated as an observer in both sessions, collecting information and analysing feedback from the attendees.

The workshop aimed at introducing AstroEDU to both teachers and researchers involved in education. It provided a comprehensive understanding of how to use and create high-quality educational resources that can benefit educators worldwide. Overall, **299 participants accessed the two sessions, with 211 staying online for more than 30 min (121 for the first and 90 for the second).**

Each session lasted between one and a half hours and two hours and consisted of three parts:

- **Part 1 (30 min):** a presentation of AstroEDU, providing an overview of the platform. Topics addressed: AstroEDU and its vision, the publication process, activities published to date, visitors' profile, and how they use AstroEDU.



- **Part 2 (1 hour):** a practical exercise for participants on how to transform an educational activity into an AstroEDU online resource, analysing two different case studies. This segment of the workshop was also interactive thanks to polls and questions asked via chat (see below the results).
- **Part 3:** a Q&A session during which participants could pose their questions about AstroEDU. Participants were also asked to share their background and previous experiences with the AstroEDU platform via chat (see the results below).

Analysis of the participants

The main results from the analysis of the participants in the 2 sessions of the workshop can be summarised as follows:

- **Professional diversity:** the profiles of participants were very diverse. These include educators, astronomers, educational project coordinators, scientific communicators, and researchers from renowned institutions in various countries, university professors, and professional from the technical sector. This variety underscores the interdisciplinary approach to astronomical education, integrating different skills and perspectives.
- **International involvement:** participants are based in a range of countries, such as: France, Argentina, Spain, Qatar, Ireland, India, Turkey, Iran, Syria, Egypt, India, and Brazil. In addition, many work for various European institutions. This highlights the strong international interest in astronomy-based education and an extensive collaboration network.
- **Specific roles in education and astronomical dissemination:** many participants are responsible for activities such as coordinating astronomical educational projects, managing observatories and planetariums, and university and school education.
- **Prominent organisations and diverse sectors:** some participants are affiliated with relevant organisations, such as the IAU Office of Astronomy for Education, and internationally renowned universities.
- **Focus on innovation and communication:** some participants have roles related to innovation in communication and educational technology, indicating an interest in using new technologies and methods to enhance astronomical education.

Summary of comments and questions

The interaction with participants, including their feedback and questions, indicated that:

- AstroEDU is recognised as a global educational platform. It is widely used and appreciated, with a wide range of activities that inspire educators and students in the field of astronomy worldwide.
- AstroEDU resources boast wide applicability. They are used at both school and university level, and by professionals from different regions and with diverse profiles.
- The impact of AstroEDU goes beyond the mere provision of teaching materials. In fact, AstroEDU promotes collaboration and innovation, supporting the teaching and learning of astronomy at an international level.
- Educational objectives vary greatly, indicating a diversity of approaches and interests. Although the focus is on astronomy, other subjects such as Earth, geography, and art play an important role.

- There is a strong interest in making the learning of astronomy, and science in general, more engaging and accessible. To this aim, strategies such as creative metaphors and captivating stories, which can attract students' attention, are deemed very valuable.
- Participants emphasised the importance of high-quality teaching resources and the need for educational tools that stimulate curiosity and deep understanding.

Finally, a number of inquiries posed in the Q&A will lead to further analysis and consideration:

- There is a strong interest on how to share astronomical educational resources through AstroEDU, and many questions were asked about the possibility of sharing personal activities on the platform.
- There is a strong awareness of geographical and linguistic differences in the production and use of educational resources. Specific requests for materials available in multiple languages were made, including the possibility to publish single activities in languages where there is no local edition of AstroEDU.
- The questions also show attention to the overall usability of the resources, investigating their usefulness in different geographical and educational contexts.

Conclusion

The workshop highlighted the value of the AstroEDU platform as an educational tool in the field of astronomy and science in general. It offered fertile ground for sharing best practices and discussing new teaching approaches. The experiences and questions raised during the workshop will be crucial in guiding the future development of AstroEDU, thus contributing to more effective and engaging learning in astronomical sciences.

Arabic-Speaking Community Discussion

Session organisers: OAE-Egypt

Astronomy in the Arab Culture and Bridges of Cooperation

Speakers: Dr. Ali Al-Azzary, Iraq, Dr. Ahmed Shaalan, Lebanon, Ms. Dalal Al-Lala, Jordan, Tariq Al-Khatib, Syria. Abdul Latif Bendhou, Morocco, Ms. Maryam Al-Qassab, Bahrain, and Dr. Somaya Saad, Egypt

Moderators: Dr. Somaya M. Saad and Dr. Abd Al-Fady B. Morcos

DISCUSSION SUMMARY

The talks ranged as follows:

Dr. Ali Al-Edhari spoke about how to use infographics to teach astronomy in areas with limited resources: for example in Iraq. He explained that this is a project to teach astronomy that depends on converting data, information, and basic concepts of astronomy into images (static or moving) that are easy for the student to comprehend and memorise. He gave many examples of how to convert the information to a photo, such as a satellite. He also related the stages of stellar life stages, sizes and evolution to the human life cycle. Finally, he explained that this method may also be very useful in special cases where it is difficult to get this information using traditional methods of education.

Dr. Ahmed Shaalan presented the film “When the Sun Dies” in Arabic. It deals with the stages of star development in a simplified and attractive way. The duration of the video is 20 minutes. It is suitable as teaching material for pre-university education.

Ms. Dalal talked about the “Arab Contributions to the Development of Astronomy”, where she displayed many facts about astronomy in the Arab culture, schools, astronomical observatories, and Arab scientists. As well as the cultural and religious importance of astronomy, astronomical instruments, and innovations. She also talked about how to build bridges of cooperation between Arab cultures.



Mr. Tariq Al-Khatib spoke on “Astronomy Education in Syria” in light of the many challenges and lack of resources, and on the role of the Syrian Astronomical Society in disseminating astronomy education. He also presented many astronomical activities.

Ms. Maryam gave a talk on “Training School Students on Astronomical Programs” and presented many programs, links and resources available, which can be a good way to teach students how to access, reduce, and analyze astronomical data in an interactive way.

Mr. Abdel Latif spoke about the “Pedagogy for Teaching Astronomy, Eratosthenes’ Experiment as a Model”. He introduced the concept and explained the experiment.

Dr. Somaya introduced the “Astronomical Legacies and Their Role in Teaching Astronomy and Bridges of Cooperation”. She reviewed astronomical legacies in Arab societies and how to use them as an entry point for teaching astronomy, as they are easy for everyone to understand and touch on it, which contributes to teaching astronomy in an interactive manner. She gave examples that can be used, such as: astronomical myths, manuscripts, observatories, books and tools, astronomical natural phenomenon, astronomical architecture, etc. In addition, she highlighted the importance of teaching the history of Arab scientists and their contributions to the development of science and astronomy.

Audiences from Arabic-speaking countries participated by listening. Each talk lasted 20 minutes, over two hours. The talks were followed by an hour-long discussion.

The session ended with the following recommendations:

First: Organising periodic meetings with Arab participation to enhance cooperation and exchange experiences.

Second: Enriching the Arab library with books in the fields of astronomy, focusing on translating and publishing selected scientific books in the Arabic language.

Third: Developing educational content aimed at children to arouse their curiosity for astronomy and space sciences.

Fourth: Launching Arab events and organising exhibitions to disseminate educational activities about the Arab astronomical heritage and increase awareness.

Fifth: Developing joint e-learning programs by establishing Arab electronic platforms for teaching astronomy that provide educational materials and training courses via the Internet.

Sixth: Developing school curricula to include astronomical heritage, including Arab astronomical heritage in the curricula to enhance identity and cultural awareness.

The session reflected the keenness to strengthen Arab cooperation in the field of astronomy education, scientific research, and interest in preserving the Arab astronomical heritage.

Hebrew-Speaking Community Discussion

Session organisers: Ayelet Weizman (NAEC Israel), and Hila Yeshurun (manager of Horizon)

DISCUSSION SUMMARY

The special session in Hebrew was very successful. It was organized by the NAEC Israeli team together with the Israeli space education community “Horizon”, which is supported by the Israeli Space Agency.

The session included eight presentations of a variety of space education activities that were initiated by educators in Israel. The participants of these activities included target audiences, from kindergarten children, to high school students, in formal and informal learning contexts, and in academic courses. All the presenters were members of the “Horizon” community.

Finally, there was a general discussion on various aspects of space education in Israel. One of the issues raised in this discussion was the need for formal assessment of all the activities and initiatives. We plan to use the assessment toolkit that was provided by IAU.

These were the presentations included in the session:

- 1. Hila Yeshurun: Horizon – The Space Education Community in Israel**
Hila described how the community brings together people from the space industry, academia, and education to create an ecosystem for the benefit of Israel's children.
- 2. Inbal Israel: Stargazing from Home - Space Lectures in War Time**
In order to maintain a study routine for students during the current war situation in Israel, Inbal organized a series of online lectures on space and astronomy. Many community members joined this initiative and volunteered to give online lectures.
- 3. Shelly Vexler: To Infinity and Beyond – Developing Wonder in Kindergarten**
Shelly described how young children (4-6) developed the sense of wonder through inquiry based projects, in science in general, and space in particular.
- 4. Einat Ben-Eliyahu: Space Olympics for Elementary Schools**
The conference dealt with the development of social and emotional skills in leading student teams in science and technology projects based on PBL. In the light of leading student teams in the Israeli Space Agency's Space Olympics.



5. **Tali Korach & Nisim Haham: By the Age of 16 You Will Find an Asteroid. Learning About Space Through the IASC Project**

Tali and Nisim talked about the IASC asteroid detection project they led, as an opportunity for meaningful learning, teamwork, engagement and shaping of the personal identity of the participants.

6. **Dov Ruso: Integrating Space Education into the Formal K-12 Education System**

Dov presented data from his doctorate studies, about the attitudes and perceptions of students, teachers, and graduates towards space education within the framework of formal education.

7. **Nir Dubrovsky, Majd Thabit, Osnat Eldar: We are all Residents of the Milky Way. A Multicultural Project Connecting Cultures Through Space**

We heard about joint initiatives between the Arab and Jewish societies. Space can connect between sectors and cultures and make it possible to remove barriers and prejudices.

8. **Ayelet Weizman: Preparing the Next Generation of Space Educators. Space Education at College Level**

In the M.Ed. program in Ed.Tech. at Kibbutzim College of Education, Ayelet leads a unique track. It focuses on space as a context for training educators to incorporate innovative technologies and important skills in teaching that will shape the citizens of the future.

Portuguese-Speaking Community Discussion

Session organisers: Eduardo Penteado (OAE Heidelberg), Rosa Doran (NAEC Portugal), Thomson Mucavela and Cláudio Paulo (both NAECs Mozambique)

DISCUSSION SUMMARY

The Portuguese language, spoken as the official language across various nations, including Portugal, Brazil, Angola, Mozambique, Cape Verde, and others, unifies over 260 million individuals worldwide. This linguistic unity forms the foundation for cultural collaboration and presents a significant opportunity for fostering educational endeavors, particularly in the realm of astronomy education.

The imperative for practitioners in astronomy education to share experiences and knowledge cannot be understated. This field serves as a gateway to unraveling the mysteries of the cosmos, offering a platform for interdisciplinary learning and scientific exploration among diverse communities.

Discussions with participants of our session highlighted the need for deeper collaborations and partnerships. Participants emphasized the importance of ongoing exchange programs, joint research endeavors, and the establishment of international forums to facilitate dialogue and the exchange of resources among educators and researchers across these nations.

During our event, Gustavo Iachel, from the State University of Londrina, Brazil, delivered a comprehensive talk summarizing the trajectory of astronomy education in Brazil. His presentation offered valuable insights into the developmental milestones and initiatives that have shaped the landscape of astronomy education in the country.

Reflecting on the rich history of astronomy education in Brazil, which commenced in 1973 with Rodolpho Caniato's pioneering work, we can observe that numerous pivotal moments have contributed to its evolution. These include pivotal events such as the Brazilian Meeting on Astronomy Education (EBEA), the Brazilian Astronomy and Astronautics Olympiad (OBAA), the National Symposia on Astronomy Education (SNEA), and others.

Drawing upon Pierre Bourdieu's conceptualization of scientific fields, the autonomy of Astronomy Education as an independent social space governed by its rules and dynamics is evident. This autonomy has allowed the field to create and disseminate new knowledge while maintaining its integrity and resisting external pressures.



Despite occasional setbacks, such as the discontinuation of events like EBEA, the resurgence and consolidation of Astronomy Education post the International Year of Astronomy in 2009 (IYA2009) have been notable. The field has witnessed a surge in publications, the emergence of new researchers, and sustained interest in advancing astronomy education within Portuguese-speaking communities.

Acknowledging the importance of collaborative endeavors and significant milestones, astronomy education within Portuguese-speaking nations continues to progress. The spirit of perseverance and collective endeavor guides our path forward, fostering a deeper commitment to furthering astronomy education across culturally diverse and interconnected nations.

Talk Summary: “History and consolidation of research in astronomy education in Brazil” by Gustavo Iachel, Londrina State University, Brazil

The research in astronomy education in Brazil carries a fascinating history (IACHEL, 2013), commencing in 1973 with Rodolpho Caniato. By defending the thesis “A Brazilian project for Physics teaching”, he addressed the question of integration of astronomy into physics education. By publishing the volume “O Céu” (CANIATO, 1973), he became a pioneer in presenting experiments for teaching this science in schools.

Caniato’s active participation in the VII National Symposium on Physics Teaching (SNEF) in 1987 was significant, generating debates on astronomy content in elementary education and teacher training. This meeting provided a permanent space in physics teaching events, stimulating the formation of work groups in subsequent events. During the IX SNEF in 1991, a work group on astronomy teaching was held, further strengthened in the X SNEF in 1993 (NARDI, 1993). In this context, changes were sought in the initial teacher training, given the insertion of astronomy content in the school curriculum, especially in the state of Paraná. Despite the recommendation not yielding the expected effects, a group concerned with astronomy teaching, the GEA (Trevisan, 2011), was consolidated. This group proposed the formation of the Teaching Commission of the Brazilian Astronomical Society (COMED-SAB) in 1993.

Three years after the X SNEF and the creation of COMED, the first Brazilian Meeting on Astronomy Education (EBEA) took place in Campinas-SP. Until its seventh edition, the event was held in conjunction with the meetings of the Brazilian Planetarium Association.

The 1990s saw a significant increase in the number of papers published in the field, possibly due to the publication of the National Curriculum Parameters (PCN) in 1998 (BRASIL, 1998). This official document had a positive impact by organizing knowledge related to astronomy in the school curriculum. In the same year, the activities of COMED-SAB converged to create the Brazilian Astronomy and Astronautics Olympiad (OBAA).

Between 2004 and 2009, there was a relative pause in the organization of highly visible events, except for the continuous execution of OBAA. However, the number of dissertations and theses on the topic grew quantitatively and qualitatively. In this period, Bretones and Megid Neto (2005) organized the Theses and Dissertations Bank in Astronomy Education (BTDEA), which stands out as an important fact.

From 2009 to the Present:

The year 2009 was crucial for education and research in Astronomy Education in Brazil when UNESCO defined it as the International Year of Astronomy (IYA2009). During this period, the Regional Meetings on Astronomy Education (REMA) emerged as part of the celebrations. These

meetings boosted activities carried out by OBAA, resulting in more than 70 basic Astronomy events in various regions of the country.

The “boom of 2009” inspired the founding of the National Symposia on Astronomy Education (SNEA) in 2011, providing a crucial platform for researchers in this scientific field. Since then, six editions of SNEA have taken place, bringing together the main researchers in the field of astronomy education until 2022.

The trajectory of Astronomy Education in Brazil includes several crucial moments since 1973. The emergence of researchers interested in astronomy, the creation of the Teaching Commission of Astronomy at SAB, the elaboration of PCN, and the emergence of events like EBEA, OBAA, SNEA, and EREA, along with the launch of RELEA, are factors that were driving the growth of the field. In 2009, the International Year of Astronomy catalyzed interest in research, and some local nodes, maintained since AIA2009, may become future reference centers in the country.

Scientific Field in Astronomy Education: An Analysis Based on Pierre Bourdieu

The conceptualization of the scientific field, based on Pierre Bourdieu's studies (Bourdieu, 2004), reveals that it is an autonomous social space governed by its own rules. Bourdieu highlights the importance of escaping from “pure science” and “slave science”, seeking a balance between social, political, and economic issues. The scientific field, as a social world itself, imposes its own rules and is relatively independent of external pressures.

The autonomy of this field, measured by the ability to create and maintain its own rules, indicates its refractive power in the face of external pressures. The distribution of scientific capital among agents, individuals, and participating institutions defines the structure of the field. The weight of certain agents, determined by their political or intellectual capital, can deform the space around them, influencing the dynamics of the scientific field.

Consolidation of the Scientific Field in Astronomy Education:

Based on the above, there seems to be enough intellectual and political capital to generate new knowledge and to fight for the initiation and maintenance of its own space in the scientific field of Education in Astronomy in Brazil. Despite some setbacks, such as the extinction of events like EBEA, there is a resumption of the field from AIA2009, and, as the number of publications increases and new researchers are trained, the Scientific Field of Education in Astronomy seems consolidated in the country. The acknowledgment of crucial moments since 1973, shows a solid path, strengthened by debates, events, and initiatives that shaped Astronomy Education in Brazil.

Ad astra per aspera.

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Romanian-Speaking Community Discussion

Session organisers: Felicia Călmuc and Elisabeta Ana Naghi (both NAECs
Romania)

DISCUSSION SUMMARY

This year, as part of the 5th SHAW IAU WORKSHOP, there was a session organized for the Romanian astronomy community in their maternal language — an event highly appreciated by all participants who expressed their gratitude for having this great opportunity to share their experience as astronomy educators and promoters in Romania. The session was coordinated and moderated by Ms. Elisabeta Ana NAGHI, the Romanian NAEC and inspector for Mathematics and Astronomy at the Romanian Ministry of Education, with the support of Felicia Elena CĂLMUC, English teacher for nonformal education at Palatul Copiilor, city of Craiova.

The main topic of the Romanian session, entitled **KNOWING THE UNKNOWN**, was *EDUCATION FOR ASTRONOMY IN ROMANIA- A STEAM APPROACH*. The session can be considered a real success, as approximately 70 people (astronomy specialists and teachers involved in astronomy education) from institutions and schools from all over Romania took part in the event, directly or indirectly, on November 30th, from 4 to 6 p.m. UTC.

The session started with a speech held by Ms. Magda STAVINSCHI, researcher at The Astronomy Institute of the Romanian Academy (where she worked as a manager for 15 years) and president of the 46th IAU Committee — Astronomy Education and Development (2006-2009). She made a presentation about the History of Astronomy in Romania to emphasize the context in which astronomy education should be approached scientifically.

The following presentation — *ASTRONOMY NOWADAYS* — was held by Ms. Elisabeta Ana NAGHI, the Romanian NAEC, together with Daniel CAUTNIC, a student from Samuel von Brukenthal High School in Braşov. They presented an overview of astronomy activities in Romania during the past years within the context of the development of the astronomy curriculum for the primary level of education. They focused on the project *START IN THE ADVENTURE OF KNOWING THE UNIVERSE*, approved by the Romanian Ministry of Education in 2022 (the contributions were presented by Ms. Maria Borşan, a teacher at the primary level of education and the team coordinator). They also discussed the development of an astronomy curriculum for the secondary level of education, which has just begun under the coordination of Mr. Iulian STANCU, a Physics teacher. Speakers emphasized three main types of activities, namely:

TYPE 1- TEACHER TRAININGS all over the country held by the Ministry of Education in *TEACHER TRAINING HOUSES* (for more than 200 teachers), followed by

TYPE 2- TEACHER TRAININGS IN *SCHOOLS* with the contribution of ESERO and teachers trained during TYPE 1 activity



TYPE 3- ASTRONOMY ACTIVITIES INVOLVING TEACHERS, STUDENTS, AND PARENTS (with more than 500 participants) organized both indoors and outdoors with the contribution of school management, local authorities, and educational NGOs. Approximately 70 teachers presented the astronomy activities held in their schools, including the implementation of the astronomy curriculum for primary level as well as IAU projects, which have recently become a tradition all over Romania (**WOMEN AND GIRLS IN ASTRONOMY, DARK SKIES, ASTRONOMY DAY IN SCHOOLS**, etc.).

There were also speeches presented by Mr. Petru CRĂCIUN, coordinator of the Romanian teams participating at the INTERNATIONAL ASTRONOMY AND ASTROPHYSICS OLYMPIADS, Ms. Cristina STANCU, coordinator of the ESERO-ROSA BUREAU, and Mr. Cosmin MICLOȘ, president of the association APPRENTICE ASTRONOMER from Brașov and a promoter of astronomy education in Romania.

In addition, there was a poster presentation titled “Unfolding the Unknown: Astronomy Education in Romania” by Elisabeta Ana Naghi.

Poster link: <https://doi.org/10.5281/zenodo.10445364>



In the conclusion, the Romanian NAEC emphasized that all Romanian astronomy educators and promoters would be a part of the national educational network called RO- ASTRONOMY AND SPACE COMMUNICATION. This integration would provide them with an opportunity to work together and share their experiences. Within this context, all the schools and institutions that organized astronomy activities were added to a Romanian geographical map presented during the session. Everybody was glad to notice that all the regions of the country were covered, which is, in fact, the main purpose of the astronomy educational activities coordinated by the Romanian NAEC, Elisabeta Ana NAGHI, at the national level.

We would like to thank the IAU and we hope to take part in such events also in the future.

Spanish-Speaking Community Discussion

Session organisers: Samantha Brown-Sevilla (OAE Heidelberg), Breezy Ocaña Flaquer (NAEC Dominican Republic), and Juan Ángel Vaquerizo (NAEC Spain)

DISCUSSION SUMMARY

The Spanish session provided an opportunity to bring together both the Spanish-speaking NAECs and the teachers from this large language community. The session had three main goals: to listen and learn from teachers' experiences in introducing astronomy in their school classes; to foster collaborations between the attendees; and to motivate them to start planning a regional conference centred on teachers' experiences.

To achieve this, the NAECs were asked to invite teachers in their network to share their experiences during the session. The goal was to have contributions from different countries, and different educational levels, both in public and private education. This led to 14 contributions from 10 different countries that covered a wide range of educational levels from 1^o to 12^o grade, including special education for students with disabilities, and teacher trainings. Some teachers sent their contributions as a video, and some shared it live during the session. The contributions are listed below with the teacher's name, title of the activity, educational level, and country specified. The activities were classified into the following categories: hands-on activities, co-education, training, planetarium, and citizen science.

The presentations included in the session were:

- **Mariela Alejandra Corti: Astronomy activities, 12^o grade, Argentina**
Mariela told us about the different activities she organises at the Universidad de la Plata secondary school in Buenos Aires to explain astronomical events associated with the Sun.
- **Marbella Hernández García: Solar System to scale, pre-school to 12^o grade, Mexico**
By using fruits and seeds known by the students, Marbella carried out an activity to represent the Solar System to scale. This was one of many activities that she has implemented in her classroom with the guidance of astronomers from the "Instituto de Radioastronomía y Astrofísica" in Morelia.
- **Anicet Cosialls Manonelles: The Moon in detail, 11^o and 12^o grade, Spain**
In this activity, the students had to estimate the Moon's radius, gravity, and density using pictures of the Moon that they took themselves. Anicet also encouraged them to come up with ideas on how to create a 3D image of the Moon from the pictures.



- **Jack Martín Costilla Soza and Erick Meza: Astronomy in rural schools near the Monquegua astronomical observatory, 4°, 10°, and 11° grade, Peru**
Jack told us about the workshops they organised to bring astronomy to the rural area of Monquegua. The workshops included building small devices from common materials to explain or observe different astronomical phenomena. They also organised observation of astronomical events.
- **Alejandra Duque Ceballos: Build your own space mission with food, 3° to 5° grade, Colombia**
In this activity, Alejandra explains the basic elements of space missions to the students, and then they build one using cookies and a typical sweet from Colombia.
- **Marta Lilian de la Cruz: Solar and Lunar Eclipses, History of Astronomy, Solstices and Equinoxes, 6° to 9° grade, El Salvador**
Using easily accessible materials, such as light bulbs and Styrofoam pellets, Marta organises various activities to explain these astronomical phenomena in the classroom. The activities are based on the NASE educational resources.
- **Ricarte Gómez: Astronomy Fair, 7° to 9° grade, Panama**
After taking the course from NASE, they implemented activities to teach astronomy into the curricula and organised an astronomy fair for the whole school. During the fair, they built and replicated most of the experiments from the NASE course and also made use of a virtual planetarium.
- **Laura Lorena Caminos: SEI Astrochikis Club, 1° to 5° grade, Colombia**
Laura told us about the “Semillero Escolar de Investigación Astrochikis Club,” founded in Bogotá in 2017 as a space for kids interested in astronomy. The kids apply what they learned to teach astronomy in daily life and develop the “Being Citizens of the Cosmos” proposal.
- **Paola Ochoa: Basic Astronomy and Astrophysics and Observational Astronomy, teachers, Bolivia**
Paola and the rest of the NAEC team organise courses for teachers of observational astronomy to enable them to use the telescopes in their classrooms. These courses last 12 hours and take place in different cities of Bolivia, covering the whole country.
- **Maria Ángela del Castillo Alarcos: Marvelling at the Universe, 1° to 12° grade, Spain**
Maria is the director and promoter of the School of Science COSMOFISICA in Titaguas, Valencia. For the last 25 years, the school has been dedicated to the dissemination of astronomy through a planetarium, an astronomical observatory, and workshops.
- **David Portillo: The Universe and you, 11° and 12° grade, and youth with disabilities, Venezuela**
The main objective of these activities is to bring the basic knowledge of astronomy to schools, high schools, and universities. David makes this possible by tailoring the activities at the SB Planetarium to the needs of the audience.
- **Juan Carlos Terrazas Vargas: Astronomy courses in Bolivia, 6° to 12° grade, Bolivia**
Through online lectures, hands-on observational activities, and research projects, Juan and his team accomplished the goal of enriching the knowledge of the country’s participants who did not have a background in astronomy.
- **Maximiliano Alzate Beltrán: Astronomy 360 degrees, 4°, 5°, 7°, 10°, and 11° grade, Colombia**
By means of a planetarium dome, 4k projection, and immersive sound, Maximiliano and his team immerse students in the field of science and astronomy.

- **Julio Vannini: Asteroid identification, 7° and 8° grade, Nicaragua**

Julio and his team carry out asteroid identification activities with the IASC (International Asteroid Search Collaboration) project and the Astrometrica software.

A total of 32 participants attended the session. After the teachers' presentations, we had six additional contributions from the audience followed by an open discussion. The resources shared during the discussion are listed at the end. This session allowed us to identify shared challenges and needs across various countries, leading to productive discussions that sparked collaboration among participants. Having such a large number of contributions further reinforced the idea of organising a regional meeting focusing on teachers' experiences.

The participants were also invited to become translators for the OAE glossary of astronomical terms. They were also reminded of the upcoming launch of AstroEDU in Spanish.

Shared resources:

- <https://www.youtube.com/@enSENAmeastronomia>
- <https://www.cosmoamautas.org/maestros.html>
- <https://lco.global/education/partners/training-novae-hunters/>
- <https://www.apea.es/>
- <https://argonavis.ar/>
- <https://www.iac.es/peter>
- <https://issuu.com/editorial-usach/docs/9789563035223>
- <https://drive.google.com/file/d/1zkJQmN5vr2FjCki0gQcmJE3xT4QFwa6X/view>

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