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Proceedings for the 4th Shaw-IAU Workshop on Astronomy for Education

Leveraging the potential of astronomy in formal education

15 – 17 November, 2022

IAU OFFICE OF ASTRONOMY FOR EDUCATION

OAE

Editors: Asmita Bhandare, Eduardo Penteado, Rebecca Sanderson, Tshiamiso Makwela, Niall Deacon, Moupiya Maji, Emmanuel Rollinde, Francesca Cresta, and Aniket Sule

Publications of the IAU Office of Astronomy for Education

Compiled & Edited by:
Asmita Bhandare, Eduardo Penteado, Rebecca Sanderson, Tshiamiso Makwela, Niall Deacon, Moupiya Maji, Emmanuel Rollinde, Francesca Cresta, and Aniket Sule.

The following is a collection of summaries from the 4th Shaw-IAU workshop on Astronomy for Education held 15 – 17 November, 2022 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/4th-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).

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THE SHAW PRIZE 邵逸夫獎

Foreword

4th Shaw-IAU Workshop on Astronomy for Education

What would you need to know to be able to strengthen the role of astronomy in schools? You might want to look at how curricula are created in the first place, and you will want to profit from the experiences of those who have already been successful in including astronomy in their countries' curricula. You would likely be interested in the various roles that astronomy can play in practice, in both primary and secondary schools. You might turn to astronomy education research for answers to questions about what fosters student interest in the STEM subjects science, technology, engineering and mathematics — and since at least part of the answer appears to be that cutting-edge results, such as those involving black hole shadows or exoplanets, are of particular interest to numerous students, you might want to look into including those topics in school teaching. Last but not least, you might look for synergies between astronomy and raising awareness for one of the most pressing challenges of our time: climate change.

That, at least, were our assumptions when we considered which sessions to include in this year's Shaw-IAU Workshop, and from the feedback received so far, we seem to have hit the mark. The workshop itself was truly global, with 600 participants from more than 90 countries. We particularly salute those participants who had to make special efforts to attend, circumventing state-imposed restrictions on international communication. With these proceedings, as well as the videos and posters from the workshop that are available online, we make the various contributions available beyond the confines of the workshop itself.

Although the total count is only up to four, the Shaw-IAU Workshops have already become something of an institution. Their genesis, of course, is directly linked to the International Astronomical Union's establishment of its Office of Astronomy for Education in late 2019, hosted at Haus der Astronomie and the Max Planck Institute for Astronomy in Heidelberg, Germany, and the evolution of the Shaw-IAU Workshops has paralleled the building of the OAE as a whole. The online format started out in 2020 as a pandemic necessity. But we soon realised that the kind of online meeting the Workshops provided was a highly accessible format that would allow us to make these workshops truly global, and to set the threshold for participation as low as possible. We acknowledge that there still *is* a threshold – since internet access with sufficient bandwidth is required – and we will continue to look for ways of increasing accessibility even further. Perhaps the hybrid format pioneered by the OAE Center China-Nanjing this year, which combined the virtual and international Shaw-IAU Workshop with an in-person teacher workshop (as well as a nation-wide online workshop) is a model for the future?

On the part of the Office of Astronomy for Education, we hope that these proceedings will help you to make better and more effective use of astronomy in support of primary and secondary school education. It's a big universe out there — let's encourage students to explore it!

Markus Pössel
Director, IAU Office of Astronomy for Education
Heidelberg, December 2022

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

Astronomy and Curriculum

Astronomy in Schools: How Do You Get Your Administration and Your Ministry to Listen?

Session organisers: Tshiamiso Makwela (OAE Heidelberg), Markus Pössel (OAE Heidelberg), Li Jian (OAE Center China, Nanjing), Farseem Mohammedy (NAEC, Bangladesh), and Li Peng (OAE Center China, Nanjing)

Session overview

One of the goals of the Office of Astronomy for Education (OAE) is to professionalise astronomy education for formal education in primary and secondary schools. The main challenge that is faced in many parts of the world, is that astronomy is not included in the schools' curriculum. Introducing astronomy in the curriculum means, planning and designing content, material, and activities for that section. In this session, we will hear from astronomy professors, lecturers, and teachers who have had the experience of advocating for astronomy education in schools, with the ministry of education.

In this session, the speakers have had the opportunity to advocate for the inclusion of astronomy within their school curricula. An interesting aspect of this lies in the fact that the outreach initiatives alone are not sufficient to make astronomy well-known to the general public. As such, the more practical way of improving astronomy literacy, is through entering astronomy in formal school. Another interesting aspect, brought through by the invited speaker is that when the ministries and governments are already open their ears to listen, collaboration can be fostered to ensure the inclusion of astronomy within the curriculum.

The key aspects of advocacy include initiating, communicating, educating, and collaborating. Initiating means taking the first step, and in the context of astronomy, taking the first step in acknowledging the need for reform, access, and inclusion of astronomy in schools. Communicating, follows the initiation step, as it seeks to allow different stakeholders to engage with one another to identify key issues, problems, and solutions. Educating is closely linked to communication, as it seeks to improve the knowledge of the people directly involved i.e., the teachers (internal - through teacher training pilots), and improve the knowledge of the administrations and ministries (external). And finally, find ways to collaborate and bring the vision to fruition. These aspects we have clearly seen in the talks given in this session.

Embedding Modern Astrophysics Within the High School Physics Curriculum in Scotland

Speaker: Martin Hendry, School of Physics and Astronomy, University of Glasgow, United Kingdom

For more than a decade the national high school physics qualifications in Scotland have included key units on astrophysics, quantum and particle physics, cosmology, and relativity. The focus of these topics has been not so much what scientists have learned, but how they have done so – thus giving students (and teachers!) greater insight into general principles of scientific research, including critical thinking and problem-solving skills. The focus on open-ended enquiry also aligned with the "Curriculum for Excellence": the comprehensive reform of Scottish education carried out across all subject areas. Here I reflect on the experience of re-vamping the content and principles of high school physics education, in the context of the wider educational reform introduced in Scottish schools.

Talk link: `https://youtu.be/DolQ7LoaCn8`

In 2010 a new approach to primary and secondary education was introduced in schools throughout Scotland. Known as the "Curriculum for Excellence" (CfE), this initiative sought to achieve a transformation in Scottish education by providing a coherent, more flexible and enriched curriculum for children aged 3 to 18. The CfE aims to help every learner develop knowledge, skills and attributes for learning, life and work, and its implementation has brought about some significant changes to the physics syllabus covered in the "Senior phase" of high school.

More than a decade later these changes generally appear to have bedded in well, and have introduced tens of thousands of high school students (and many teachers!) to some of the latest developments and ideas in astrophysics, cosmology, particle physics, relativity, and quantum physics. The new material has also been presented within the context of a more open-ended approach to teaching CfE science that builds critical thinking, data analysis and other transferable skills; in this sense, the inclusion of more (astro)physics content has been important as much for what it conveys to students about *how* we have come to understand the cosmos, as it is about *what* we have learned.

Key to the successful implementation of these exciting developments has been the teacher support and infrastructure created and maintained by numerous stakeholders that include Education Scotland and the Scottish Qualifications Authority, the Institute of Physics in Scotland, the Scottish Schools Education Research Centre (SSERC), Scottish University departments of Physics and Astronomy and the Scottish University Physics Alliance.

The CfE Higher and Advanced Higher Physics Courses

While the CfE has sought to foster positive changes in the teaching of science at all levels, in this short report I will focus solely on the "Higher Physics" and "Advanced Higher Physics" courses taught during the Senior Phase of High School (usually students' fifth and sixth year of study).

The Higher Physics course comprises four teaching units, three of which have been significantly updated:

- In "Our Dynamic Universe" students are introduced to the basic concepts of special relativity (including time dilation and length contraction, deriving the relevant formulae from first principles), the Hubble expansion and evidence for the hot Big Bang (including black-body radiation and the cosmic microwave background radiation).

- In "Particles and Waves" students learn about qualitative features of the Standard Model of particle physics, emphasising not just how far this theory has come but also where the remaining gaps in our understanding lie. Particles and Waves also introduces the key ideas of wave-particle duality, focusing on the photoelectric effect, the double slit experiment and its implications for a quantum description of reality.

- In the new "Researching Physics" unit students undertake a short piece of research on a topical subject of their choice. Popular subjects that schools have chosen include, for example, exoplanets – where students learn about exoplanet detection methods and e.g., analyse transit light curves, to test simple hypotheses.

The **Advanced Higher Physics** course also comprises four teaching units, with again three of them re-vamped to contain enhanced astrophysics / relativity / quantum physics content:

- In the new "Rotational Motion and Astrophysics" unit, students build upon special relativity covered in the Higher Physics course and are introduced to the key ideas of general relativity via the Equivalence Principle, to a qualitative discussion of the geometry of curved spacetime and to simple calculations related the Schwarzschild radius and the event horizon. This unit also includes a basic description of the lifecycles of stars and the Hertzsprung-Russell diagram.

- In the re-vamped "Quanta and Waves" unit, more basic quantum physics is introduced - including the Bohr atom and the concept of the de Broglie wavelength – that significantly extends the material covered in the Higher course.

- Finally, in the "Electricity and Magnetism" unit, students learn how the speed of light connects to the permittivity and permeability of the vacuum – together with the broader significance of James Clerk Maxwell's unification of the electric and magnetic fields.

Lessons learned from the Scottish experience

The inclusion of new astrophysics material has been generally popular with both students and teachers, but it has taken many teachers far from their comfort zone. Contributing to this is the fact that there is not a rigidly defined syllabus for the Higher and Advanced Higher courses but instead a series of "Experiences and Outcomes" outlining the content that students would be expected to understand. However, this flexibility in the detail of how the courses are taught in each school has resulted in an impressive degree of collegiality across schools and local education authorities. The Institute of Physics in Scotland has been a prime mover in collating and promoting these shared, teacher-led resources, and in moderating the Scottish physics teachers' online discussion forum, SPUTNIK, which many teachers use to discuss the astrophysics content and how best to teach it. These discussions have been particularly valuable around how to prepare students for the open-ended questions that are now firmly part of the national qualifications exam papers; the goal of these questions, to encourage students to "think more like a physicist" rather than relying on rote learning, is a worthy one, but is challenging nonetheless. IOP Scotland and SSERC also provide hugely valuable teacher CPD opportunities, both in-person and online, and have helped to build confidence in higher-level experimental skills such as dealing with errors and measurement uncertainties.

Overall, then, the success of the Scottish experience should give confidence to other countries or regions seeking to convince their education authorities to include more astrophysics content. Key factors that can contribute to making a strong case would appear to include:

- the political and economic demands for more STEM engagement, to address possibly significant future employment gaps and shortfalls;

- exploiting the proven popularity of astronomy amongst students, and the way in which it can build broader STEM skills that will be needed to plug these gaps and shortfalls;

- the importance of providing effective teacher support, through partnerships between universities, professional bodies and other stakeholders.

Promoting Astronomy Education in Schools: 20 years' Practice in China

Speaker: Jin Zhu, Beijing Planetarium, China

Shortly after I came to Beijing Planetarium as its curator in 2002 from National Astronomical Observatories, I realised that the 1 million visits every year to the Planetarium is far beyond sufficient comparing to the 20+ million population even in the city itself. It is obvious that making astronomy one of the courses within normal school curriculum like language and math would be a fundamental solution to have everyone enjoy the wonder and beauty of astronomy and universe. With support from the Popularisation Working Committee of the Chinese Astronomical Society and other organisations, we made different efforts with national or local projects and activities, as well as contacting administrations at different levels. Some results and lessons from the 20 years' practice are summarised.

Talk link: https://youtu.be/1nlN3_bD8U8

Twenty years ago, in Sept. 2002, I came to the Beijing Planetarium (BJP) from the National Astronomical Observatories, Chinese Academy of Science, and became the new curator of BJP. The planetarium was built in 1957 and was making the upgrade with a new building at that time. In Dec. 2004, the new building was completed and the planetarium was reopened to public. Visitors to BJP grew to more than 1 million visits (which was a sum for visitors to exhibit area only and to each of the 4 different theatres) during the next year, which was an obvious increase compared with previous years. However, I realised that such a number was still very limited compared to the more than 20 million population of the city. It will take more that 20 years to have every person in the city visit the planetarium once in their life time, considering the newly born children and large percentage of visitors from the whole country.

I realised that only a large and modern planetarium was not sufficient to make astronomy well-known to the public. The more fundamental way to solve the problem should be to have astronomy included in the formal school educational system as a course, similar to mathematics and languages. As the director of the Popularisation Working Committee of the Chinese Astronomy Society (PWC/CAS), which is usually the same person as the BJP curator, I made the statement to promote astronomy education in elementary and middle schools, and hoped that astronomy could be a part of the normal school curriculum before my retirement.

Some steps towards the goal were performed at the BJP during 2002/2003, including setting-up the Chinese National Astronomy Olympiad, adding more content on astronomy education in our Amateur Astronomer magazine, and starting an astronomy class (with teachers from the BJP) for the first year students of the Huangsongyu middle school located in a suburban area with quite good night-sky observing conditions.

Before 2000, all elementary schools and middle schools in China had the same curriculum with same teaching program and textbook. In June 1999 and June 2001, reformation of the national education system had started and the management of 3 levels of curriculum with national, regional, and school-based curriculum was implemented, which made it possible for astronomy to be selected as a school-based curriculum.

Starting from 2007, some elementary schools and middle schools in Beijing and Tianjin started their school-based astronomy curriculum. Every student had an astronomy course at least in one grade with 2 class hours per week, some even had astronomy courses in three or five grades. BJP and PWC/CAS started nation-wide teacher training programs together with other organisations like the Tianjin Science and Technology museum and the Astronomy department of the Beijing Normal University.

In Dec. 2011, I visited Nepal as part of the IAU Commission 46 (Astronomy Education and Development) Program Group for the World-wide Development of Astronomy (PGWWDA). I gave a lecture at the university there, and visited the Minister of Nepal Ministry of Education, Science and Technology to advocate for the importance of astronomy for education and social development. Based on my understanding about the importance of astronomy on education, I wrote a letter to the Minister of Chinese Ministry of Education suggesting to introduce astronomy in normal school curriculum just like mathematics, physics, chemistry, and other natural sciences.

In June 2014, BJP hosted the 22nd International Planetarium Society (IPS) Conference under the theme of “Educating for the Future”, focusing on the significant role of planetariums in future astronomy education. In Sept. 2014, Delingha Planetarium in the Haixi State of Qinghai Province was opened to the public. Delingha is the place where the 13.7-m Millimetre-wave Radio Telescope of the Purple Mountain Observatory is located. I visited Delingha (the capital city of Haixi State) with some BJP colleagues to talk to the leaders from the City and State Bureaus of Education on including astronomy courses for all Grade 7 students in the city distributed in 16 classes within 5 middle schools, with 16 90-minutes class hours each semester for every student. We helped with educational programs and the students were brought to the Planetarium for their astronomy classes.

The most successful astronomy education program in China should be the one in the Pingtang county of the Qiannan Buyi and Miao Autonomous Prefecture, Guizhou Province, where the five-hundred-meter Aperture Spherical Radio Telescope (FAST) locates. FAST started its commissioning on Sept. 2016. During the visit to BJP by the vice-governor of Guizhou Province in May 2017, I proposed that astronomy education in school curriculum is very important for every inhabitant considering the huge number of visitors at FAST. It was decided that astronomy will be a school-based curriculum for 30+ elementary and middle schools in the county from the new semester starting in Sept. 2017, and I came to Pingtang with experts from BJP and Tianjin Science and Technology Museum for teacher training courses in August. By Sept. 2020, all 82 elementary and middle schools in Pingtang County had astronomy courses in the curriculum, with a total of 36086 students and 26893 families involved.

The establishment of IAU OAE Center China at the BJP is now starting a new era of astronomy education in China.

From 20 years' practice of promoting astronomy education in schools, some experiences and lessons could be learned. The understanding from school masters and higher level authorities is important, and it is always necessary for astronomy outreach and communication with all efforts. Teacher training plays an important role in astronomy education, and local astronomy teachers in schools are more important than outside experts for a successful and sustainable program. Astronomy education in schools around some astronomical facilities might be easier to start, as well as at locations of planetariums or science museums/centers. Organisations like PWC/CAS or BJP could play an important role in this field. A systematic evaluation for the current programs may be needed for further investigation and improvement.

The New Astronomy Curriculum Pilot Program in Turkey

Speaker: Aysegul F. Teker Yelkenci, Department of Physics, Istanbul Kultur University, Turkey

A new astronomy curriculum study for secondary schools by the Ministry of Education in cooperation with TÜBİTAK (the Scientific and Technological Research Council of Turkey) is in preliminary progress since 2021. Three extended astronomy and astrophysics courses have been proposed for secondary education in science high schools in Turkey. One these courses has been approved for the pilot program to be applied in TÜBİTAK Science high school. Detailed teaching program of the "Astronomy and Universe" mandatory course is designed in cooperation with astronomers, physics teachers, course development and design experts, and evaluation and assessment experts. A group of astronomers and physics teachers are now working on the textbooks for the new pilot program starting in 2023.

Talk link: https://youtu.be/42IiVzBP8YU

In this contribution, curriculum development studies to achieve effective science teaching at the secondary level are examined. The analysis results revealed that 60% of the teachers did not find the current classical science curriculum to meet the needs of science teaching [1, 2]. The recent studies show that the information, media, and technology skill areas were the most involved in the 2018 curriculum, which is the latest version [3]. A new curriculum study for secondary schools is initiated by the Ministry of Education in cooperation with TÜBİTAK (the Scientific and Technological Research Council of Turkey) in November 2021.

TÜBİTAK science high school was chosen for the trial studies of the modern science teaching programs developed. TÜBİTAK science high school only accepts students from first 1% of the high school entrance exam and was established by the Scientific and Technological Research Council of Turkey – TÜBİTAK itself in 2021. The new pilot program aims to improve the science high school curricula by developing the mandatory and selective course programs. Evaluation studies were carried out for many new courses such as “Astronomy and the Universe”, “Innovation Oriented Project Design”, “Financial Mathematics”, “Human-Machine Interaction”, “Epidemiology”, “Polymer Chemistry”, “Future Energy Systems”, “Data Analysis”, “Artificial Intelligence Applications”, and “Ecology”.

The science high school curriculum development workshop was held in Antalya between 8-12 March 2022, within the scope of the cooperation between the Ministry of National Education General Directorate of Secondary Education and TÜBİTAK. With the participation of the head of Curriculum and Textbooks department, head of TÜBİTAK, expert academics and teachers in the workshop, development studies were carried out to ensure that the subject-acquisition-skill relationship in the related course contents of science high school is reflected effectively in the learning-teaching process.

In secondary education in Turkey, astronomy is covered in physics courses but it is also offered as a selective course in grades 9 and 10 [4]. Three new extended astronomy and astrophysics courses have been proposed for secondary education in science high schools in Turkey in 2021. One of these courses have been approved for the pilot program to be applied in TÜBİTAK science high school. Detailed teaching program of the “Astronomy and the Universe” mandatory course has been designed in cooperation with astronomers, physics teachers, course development and design experts, evaluation and assessment specialists.

A group of astronomers and physics teachers are presently working on the textbooks for the new pilot program to start in 2023.

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Astronomy Education in the Curriculum and Schools of Iran

Speaker: Maryam Papari, Ministry of education, Iran

Astronomy education is one of the favourite activities of Iranian students and teachers and in recent years we have seen a growth in the number of schools focusing on astronomy education. Mehr Observatory, as the center of astronomy education in the Ministry of Education of Iran, has prepared plans and programs in order to develop astronomical activities in schools and has implemented it in collaboration with the education departments. Astronomy education in Iran increases the academic level of students and also leads to the realisation of goals such as sustainable development, environmental protection, and the advancement of women and girls. In this contribution, we examine the official education and the role of the department of education and its support for including astronomy in Iranian school curriculum.

Talk link: https://youtu.be/YsTK6QFxyok

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Mehr Observatory is an astronomy training centre for teachers and students, belonging to the Ministry of Education, located in Bushehr province in the south of Iran. In the education system of Iran, in every city, in addition to the school, there is a student research centre, which are mostly laboratories, and the only student research centre that is an observatory in Iran is the Mehr Research Centre.

First, I would like to mention the role of astronomy in Iran's curriculum and textbooks. Despite the interest of many students in astronomy, no specialised astronomy course is taught in Iranian schools, and astronomy lessons are only introduced in the fourth, sixth, eighth and ninth grades. This is useful, but these lessons alone cannot satisfy the curiosity and answer students' questions.

According to the interest of our students and after assessing the needs and consulting with Iranian research institutes and educational institutions, with teachers who taught topics such as social sciences, psychology, art, history, literature, etc. and at the same time were also active in the field of astronomy, we held a meeting and searched for ways to increase the capacities of the curriculum in line with the development of astronomy in the country's schools.

Then, considering UNESCO's 2030 document and plan's strategy, we came to the conclusion that each of these disciplines can have a strong potential to attract students to astronomy and familiarise them with this science. So, in this way, we formulated plans for implementation to deliver to the General Administration, which after review, we can implement in schools, which is discussed in detail below.

Since the plans and activities that were prepared were not in the curriculum, we decided to organise meetings with the heads and vice-presidents of the education departments and then present and justify the plans. In the meetings, we explained the programs and since our focus was on teachers and students, fortunately, it was approved by the authorities and they decided to support the implementation of the programs.

To prove the effectiveness of the plans, we implemented them several times, such as explorers' festival, in-service courses for teachers, camping, etc.; then we presented successful examples to the education authorities, which were effective in accepting the plan.

During festivals, workshops and events, we used to invite the Education Department and authorities to visit the program. Every time the officials saw the students' interest in the sky and astronomy in the festivals and programs they decided to develop the activities and help the student's progress in astronomy.

We hope that all students who are interested in astronomy will have the opportunity to study the sky and we will not hesitate to make any effort.

Astronomy as a Tool to Improve High School Scientific Education in Peru

Speaker: Gabriela Calistro Rivera, European Space Observatory, Germany

Collaborators: Diego Alvarado Urrunaga (UNI), Daniella Bardalez Gagliuffi (Armherst University), Pamela Flores (LMU), Lisseth Gonzales Quevedo (UNMSM), Daniel Kleffman, Erick Meza (Comisión Nacional de Investigación y Desarrollo Aeroespacial del Perú - CONIDA), Vanessa Navarrete (UNMSM), ADita Quispe Quispe (IGP), José Ricra (AFARI), Bruno Rodríguez Marquina (Bonn University), Erika Torre Ramirez (UNI), Anthony Esteban Figueroa Quiñones (UNI), Sonia Diana Quispe Mamani (UNSA), and Lilian Fiorella Mucha Huaire (UC).

In this contribution, I presented the CosmoAmautas project. 'Amauta' means 'teacher' or 'knowledgeable person' in Quechua, the most widely spoken indigenous language in Peru. CosmoAmautas was developed with the vision to contribute to a stronger and more equitable scientific education in Peru, focusing on the most vulnerable socio-economic sectors that are commonly distributed in rural regions away from the capital city of Lima. CosmoAmautas is an initiative of early-career Peruvian astronomers working abroad together with astronomers with affiliations spanning most local institutions involved in astronomy in Peru.

Talk link: https://youtu.be/1YmxhS51m2Y

Figure 1: Examples of the inquiry-based learning activities done with the teachers as part of the virtual training.

Two aspects were essential in defining the CosmoAmautas educational strategy: multiplicity and self-sustainability. Therefore the core of the program are the teacher training programs, which have taken place two years in a row now, in a virtual format in six all-day sessions in 2021 and 2022. Combining the two sessions, 120 teachers from rural high schools were selected to participate in the training. We paid particular attention to gender balance and cultural and ethnic diversity in the selection of the participants, with 35% of the teachers identifying indigenous languages as their mother tongue. The teachers were selected to be representatives of 13 regions out of the 24 Peruvian regions. Through their teachers, we estimate that this initiative has reached more than 7000 high school students.

The teacher training: The six sessions were divided into different topics across all cosmic scales, including: the Earth–Sun–Moon system, Solar System, stars, exoplanets, galaxies and cosmology. Each session (six hours) was divided into two main parts. The first half consisted of hands-on inquiry-based learning activities in which the teachers explored the topic in small groups with the support of an instructor, approaching one specific question, hypothesising the answer, testing these hypotheses through experimentation, and finally presenting their conclusions. These activities included the measurement of the Earth's diameter, the comparison of Solar System scales using rice grains, the exploration of stellar parameters using a home-made spectrograph, the simulated search for exoplanets from real data, the measurement of our Galaxy's rotation using GAIA data, and the reconstruction of cosmic history using the Hubble Ultra-Deep Field image. The second half of the day consisted of interactive lectures on astrophysics, science education and pedagogy, gender balance, local ancestral astronomy, and climate change.

The virtual education system imposed by the COVID19 pandemic also revealed new necessities from the teachers in terms of virtual teaching strategies, which prompted us to redesign our hands-on inquiry learning methodology for achieving the same impact in a virtual context. This change motivated the introduction of smaller groups of teachers using breakout rooms, and we developed inexpensive and innovative digital educational tools, such as astronomy-focused educational video games tailored to complement our activities (available in Spanish on our

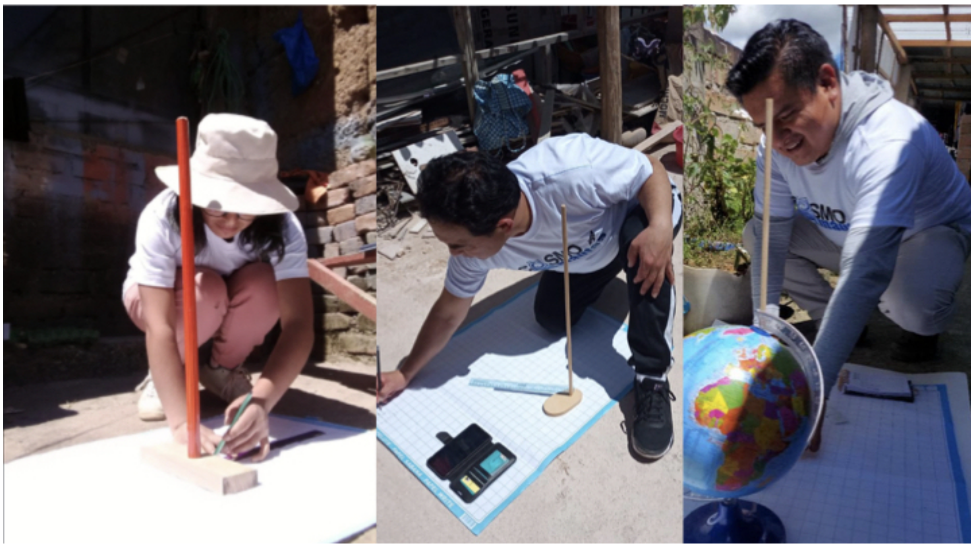

Figure 2: Teachers from different regions measuring the diameter of the Earth using the shadow of a gnome.

webpage: www.cosmoamautas.org

In order to ensure the equitable participation and engagement of teachers, we designed and shipped educational boxes across the country with all required materials to be used for the inquiry-learning activities. The materials included a text and activity book, which our team wrote to respond to a lack of accessible yet up-to-date astronomy content in Spanish at an advanced high school level. The CosmoAmautas book (160 pages, https://arxiv.org/abs/2109.11945) is a unique open-access resource for teachers who want to integrate astrophysics in their classes, combining the theoretical framework with our hands-on inquiry-learning activities.

Astroclubs: The most direct evidence of the impact of the program is the implementation of after-school astronomy clubs, 'AstroClubs', which began to take shape out of the teachers' own drive, even before the workshop sessions had culminated. From the two years of the program, more than 400 motivated students from rural high schools, aged 10 to 16, are currently exploring astrophysics topics through inquiry-based activities together with their teachers. To support their enthusiasm, CosmoAmautas has equipped each one of these AstroClubs with a telescope and 'rural' sky observation kits for all, which consist of planispheres and compasses to locate planets and constellations with the naked eye, without the need for a cell phone or other technologies.

Early indications of positive impact have been already observed, with Astroclubs organising inter-regional measurements of Earth's diameter and presenting in national conferences (ECI 2023), and participating in international measurements of Earth's diameter. Over the next few years CosmoAmautas aims to offer the teacher training workshop and to open new AstroClubs in more regions in Peru, setting a precedent for other countries with limited scientific infrastructure. In the long term we aspire to promote and decentralise the technological and scientific development of the country.

Astronomy Education for all High School Students – Challenges for the Future

Speaker: Hidehiko Agata, National Astronomical Observatory of Japan, Japan

In this contribution, examples of efforts in Japan are presented. We also call for an international survey. In Japan, the high school curriculum national guidelines that came into effect this year still require students to choose from physics, chemistry, biology, and geology (including a little astronomy) as in the past. Currently, only about 30% of Japanese high school students study astronomy. However, in order to solve various problems facing modern society, such as responding to the 3Ss (Socity5.0, SDGs, and STEAM), science, technology, and innovation, maintaining the global environment, and coping with natural disasters. A short questionnaire form regarding high school science curricula in different countries is made available.

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

How are countries trying to implement "Big Ideas in Astronomy" into school education in the future? "The Astronomy Literacy Goals" is a project by Leiden University (the Netherlands) and Institute of Astrophysics and Space Sciences (Portugal) in the framework of the IAU Commission C1: Working Group on Literacy and Curriculum Development. They published the "Big Ideas in Astronomy" first version in 2020. "Big Ideas in Astronomy" is now a project of the IAU Office of Astronomy for Education (OAE).

In Japan, the high school curriculum national guidelines that came into effect this year still require students to choose from physics, chemistry, biology, and geology (including a very little astronomy) as in the past. Currently, only about 30% of Japanese high school students study a small part of astronomy. However, to solve various problems facing modern society, such as responding to the 3Ss (Socity5.0, SDGs, and STEAM), science, technology, and innovation, maintaining the global environment, and coping with natural disasters, it is not enough to take only some of the subjects that are separated.

With an aim to include in the government curriculum guideline, we attempt to design new curriculum of science education in Japanese high school that smoothly connect from junior high school. Social problems that we face today require interdisciplinary scientific comprehension to be addressed while students learn each science subject independently. Considering the purpose of science education and its role in society, we reconsider compulsory subject for science education that should be comprehensive and foundational to nurture problem solving skills. This work is supported by JSPS KAKENHI Grant Number 22H01071 from 2022 to 2025 and we present our overall plan here.

We started a discussion on the curriculum guideline for the 2030s based on "Recommendations - The Ideal Science Education at High School" from the Science Council of Japan in 2016. Outline

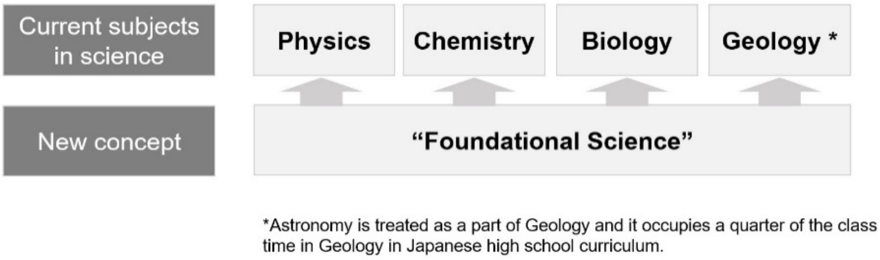

Figure 1: The Concept of "Foundational Science"

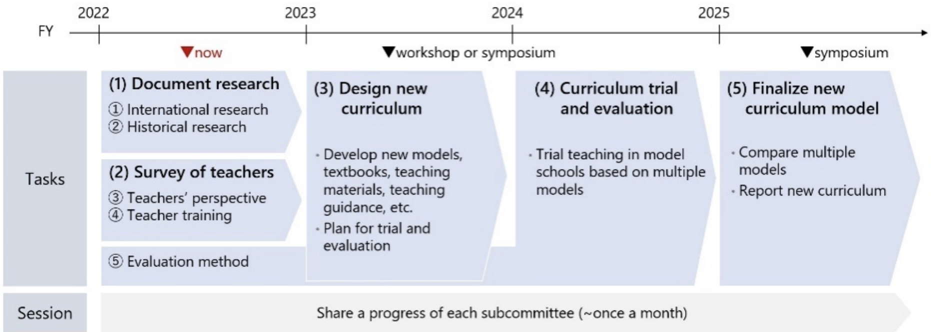

Figure 2: Schedule from FY2022 to FY2025

of the recommendations in 2016 are (I) Science education in high school should be reassessed to nurture problem solving skills under the comprehension of meaning of science and its role in society. Considering current social problems that require integration of knowledge and competency to deal with, content-based learning is not enough to tackle with social problems to be faced in the future. More specifically, the current 4 basic subjects in science should be reorganised into compulsory "Foundational Science*" (*tentative name, Fig. 1). (II) In order to cultivate science literacy for all students in high school, regardless of their choices of the course, 8 units, 6 units at least, should be allocated to "Foundational Science". In addition, to make it feasible, the system of training teachers to enable them to teach any subjects in science in general and the university entrance examination system that requires "Foundational Science" are also needed. But, unfortunately, the concept of the recommendations was not adopted in the government curriculum guideline applied from FY2022.

Therefore, a curriculum study was initiated as a voluntary research group. The research approach taken by our research group is as follows (Fig. 2). In 2022: clarify the issues of science education curriculum in high school on nurturing problem-solving skills under each sub-committee, focusing on current social problems that require integration of knowledge and competency to tackle with. In 2023-2024: design new plans for science education curriculum and execute trial classes and its evaluation. In 2025: summarise our study and recommendations to the council of Central Board of Education aligning the timeline of revision of the government curriculum guideline. Present our recommendations also to the public to spark an interest and account for the public opinion.

It is my personal view, as the principal research investigator, that I would like to install the last chapter of the "Big Ideas in Astronomy", i.e., the importance of globalism and universalism. It will help students understand the significance of learning science.

Finally, we would like to ask for a favour from you all. We would like to hear about interdisciplinary high school science education in your country. Social problems that we face today require interdisciplinary scientific comprehension to be addressed while students learn science subject separately, physics, chemistry, biology, and earth science, in Japanese high school science curriculum (age: 15 to 18). Considering the purpose of science education and its role in society, we are now discussing a compulsory subject for high school science education. We would be grateful if you would kindly inform us of science education system in your country for the comparison study. Please scan this QR code to answer a short questionnaire.

Discussion summary

Governments, administrations, and ministries of different countries have different educational policies that include their own goals and aims. However, none of them want to be recorded as "last" or "bad" in the grand scheme of things in the world, for example, being recorded as last in mathematics and English scores. Media reports on education have had an impact on the decisions that governments have to make when such critics come out. This usually gets the governments, administrations, and ministries of education attention, making them listen to people working in formal education (teachers, experts). When it comes to science, especially astronomy, this applies too, where we see the ministries gain interest based on the critics and popularisation of science in the media.

In this session, we discussed the role of administrations in formal education, where it is not always easy to implement a new curriculum especially when the administrations are not interested or detached from the everyday classroom practices. From the discussion, it is clear that teachers are the main initiators of change and reform of the curriculum. The experience that the teachers have of the content knowledge, knowledge of their learners, and pedagogy, makes them experts in the classroom. Therefore the ministries and administrations should be listening to what they have to say. The teachers know what works in terms of pedagogy, when they collaborate with experts such as astronomers, their whole package of teaching and learning improves. However, without the other, it poses a challenge, in which context may exist but it is not well taught.

This is the reason why teacher training programs are important, as these enable the teacher to gain content knowledge as well as pedagogical knowledge, together with their own knowledge of their students. Teacher training also gives teachers the confidence to use the available resources in their classrooms. Teacher training also strengthens teachers' collaborations, where teachers are aware that there is available support and that they are not alone.

When ministries, administrations, and governments, see the impact that these teacher training have in education, they are more likely to start investing in them and thus supporting the vision. This is rather a difficult thing to do, but the key is for teachers "not to give up", and to keep challenging the system. It is also important to keep in mind that education is also politically driven, as such the administrations can make decisions based on the current political state. This is why it is important to always show the connections that science and astronomy have to the current situations of the world.

How to Develop an Astronomy Curriculum

Session organisers: Tshiamiso Makwela (OAE Heidelberg), Markus Pössel (OAE Heidelberg), Li Jian (OAE Center China, Nanjing), Farseem Mohammedy (NAEC, Bangladesh), and Li Peng (OAE Center China, Nanjing)

Session overview

In this session, we will hear from astronomers, lecturers, and teachers on their experiences and work in developing an astronomy curriculum in their own country. In most parts of the world, astronomy is not included as a subject of its own in primary and secondary schools, it is either a part of other subjects such as physics, geography, or natural sciences. Astronomy continues to be a growing field of study that captures students' interests from an early age, as such, the development of an astronomy curriculum is important to equip learners with knowledge and skills that would improve their scientific literacy.

Our speakers come from different parts of the world, with diverse backgrounds and experiences, their passion for education and science, has seen them develop astronomy curricula in their specific locations. For teachers, developing the curriculum aims at improving students' knowledge and for these young students to use the skills that they gain in STEAM fields to become successful later in life, as they do not only route learn the theory but apply them in the future. Meanwhile, for astronomers and practitioners, being part of the development of the curriculum aims to ensure the transfer of content knowledge, teaching materials, and accuracy of scientific events.

For most parts, the development of the astronomy curriculum is done through a collaboration with a teacher, an astronomer/scientist, and a practitioner (a person who works in astronomy either as a communicator, curator, or amateur astronomer). This collaboration covers the basics of what is needed such as the education goals from the education standards, the layout of concepts as it is done in textbooks as well as 'the know how to' teach.

"Starting the Adventure of Learning About the Universe" a New Astronomy Curriculum for Primary level in Romania Aimed at Developing Integrated STEAM Skills

Speakers: Elisabeta Ana Naghi, ESERO, Romanian National Committee for Astronomy and Felicia Elena Calmuc, English teacher, Romania

The reconfiguration of the learning landscape, where the classroom must become the centre of innovation, the personal needs of students must be prioritised, technology must play a fundamental role, and where students must be challenged to create the future is imperative for 21st century education. "Starting the adventure of learning about the universe" is a new optional school subject for the primary level in Romania, it is part of the national curriculum and its main aim is to develop STEAM competences through integrated, inter- and trans-disciplinary approaches, key competences, as well as transversal competences. The learning activities are structured by taking into account 3 main topics: exploring the Solar System, travelling to and travellers in Outer Space and jobs of the future.

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

"Starting the adventure of learning about the universe" is an astronomy curriculum at school decision (for school subjects which are not part of the obligatory curriculum, but can be taught in schools if approved by the Ministry of Education) designed for primary level students from Romania (6 to 10-11 years old) that has been recently approved by the Romanian Ministry of Education. Therefore, all primary level teachers will have the possibility of implementing it in the classroom in the near future or can select contents to be used for school disciplines that are part of the national curriculum during the present school year. In Romania, the primary level covers 5 years for students aged 6-11 – preparatory grade, 1st, 2nd, 3rd, and 4th grades.

The process of creating this curriculum based on astronomy and space science concepts started from the idea that the 21st century school has to be more like an "Innovation center" aimed at developing new integrated STEAM skills necessary for young students to become successful teenagers and, later on, adults. In a world where nothing is possible without technology anymore, students should be offered a proper educational context that enables them not only to memorise the past, but also create the future.

From the very beginning, it was obvious that the creation of this astronomy curriculum had to involve specialists to cover two main areas: the scientific part, coordinated by the Romanian

NAEC, Elisabeta Ana Naghi and the teaching part, coordinated by a primary teacher, Maria Borsan. It is important to mention that the working group members had previously involved their students in other common astronomy projects, such as “Women in Space” by the IAU or “World Space Week”. That is why the team cohesion was not a problem, as its members knew each other and had already identified common educational issues that were to be solved by this new curriculum. Finally, six primary level and three secondary level teachers formed the working group to cover the two parts mentioned above: the scientific notions (secondary level teachers) and the teaching strategies, techniques and methods (primary level teachers). The number of teachers involved is not random, as the final form of the curriculum contains three main topics or chapters, each one developed by two primary teachers and one secondary teacher, namely *Exploring the Solar System*, *Voyages and Voyagers in the Cosmic Space* and *Jobs of the Future*.

Each of these three main chapters contain teaching activities based on concepts that aim at developing one general skill/chapter with three subsequent sets of specific skills for each general skill. All these skills are in accordance with the two school levels of the primary students, namely preparatory grade, 1st and 2nd grades (level of acquisitions) and 3rd and 4th grades (level of development and applications). The activities are designed to respect the principle of continuity and development within each school level, as well as from one level to another.

The educational resources, as well as the teaching strategies, techniques and methods were chosen with a view to making the study of astronomy and space sciences both attractive and useful for the young learners who represent the target group of this curriculum. Moreover, in the context of a society requiring integrated skills, the activities were also conceived by taking into account the modern concept of STEAM teaching and learning.

The working group also considered that STEAM activities are very appropriate for this curriculum, as there are two main options for its implementation. In the Romanian educational system, apart the main curriculum which is mandatory, schools can implement other approved curricula for a certain number of classes/week, depending on the grade and the school level. As this astronomy curriculum is approved by the Ministry of Education, it can be implemented by any school from Romania at primary level, as a distinct school subject for two years (one year for each school level already mentioned). However, there is also another possibility, namely some activities can be implemented during the classes of the mandatory school subjects for primary level (Math, Arts, Sciences, English, so on and so forth), depending on the educational needs each primary teacher identifies for their students. We consider this aspect to be a real advantage for its implementation, which is, in fact, the most important issue when it comes to such curricula.

Nowadays, it is very important for young learners to get familiar with new educational contexts that show them both the opportunities and the limitations of science. Therefore, they will better understand the world around them and later on, due to this understanding, they will be able to deal with new challenges related to finding solutions to the problems of the society they live in. These are the kind of citizens we hope our children will become one day, namely citizens prepared for the future.

Taking into account the latest discoveries in the field of space travelling, it is obvious that human society will become interplanetary at some point, in a not very far future. In this context, our curriculum also provides educational resources developed by the European Bureau of Resources for Space Education (ESERO) of the Romanian Space Agency (ROSA) based on a protocol between ROSA and the Romanian Ministry of Education designed to support astronomy education in our country.

Primary teachers who are willing to implement this curriculum will also have the opportunity to take part in training courses officially organised all over the country. At present, the Romanian NAEC is creating a database with trainers who can provide these courses. Afterwards, primary teachers will get the necessary information from the local school inspectorates to attend them. Our children will have the opportunity to explore the space themselves, it is a certainty. Our duty as teachers is to prepare them for this future and we hope this astronomy curriculum for primary level represents "Starting the adventure of learning about the universe".

Primary School Astronomy Lessons – 10 Fun and Effective Strategies

Speaker: Zhu Geya, Astronomy teacher at Zhongguancun No. 2 Primary School, Haidian District, Beijing, China

Primary school astronomy education is different from the systematic astronomy curriculum in secondary schools and universities. The astronomy knowledge itself is not necessarily the most important focus in the class, and the teaching methods and skills often account for a large proportion. In addition, the main goal of primary school astronomy education should be stimulating students' interest, and help children form the habit of "looking up at the sky". This report summarises the author's nearly 20 years experiences in primary school teaching into 10 effective teaching strategies that may inspire the readers.

Talk link: https://youtu.be/eBKZkw25OPM

This summary describes how to offer interest-oriented astronomy courses in Primary K3. Combined with nearly 20 years of teaching practice, 10 interesting and effective activity strategies have been developed to mobilise children's imagination in the classroom, spark their curiosity about the universe, and stimulate their curiosity for knowledge. For example, ask children to give themselves "astronomical names" and ask them to remember difficult astronomical terms; By issuing "Galaxy Coins", children can collect "astronomical coins" with astronomical pictures printed on them, and exchange them for astronomy books, movie tickets, game opportunities, etc. In some courses, we guide students to make "Secret Files of Mars", "Gas Mask of Venus", “Model of the Sun Structure”, and also design games such as “Celestial Collision” and “Little King Tournament”, and even use stage plays in astronomy teaching. We found that in the design of the primary school astronomy curriculum, through a variety of interesting teaching methods, it is more important to guide children to play and love astronomy than just to impart knowledge.

10 Effective Strategy Activities:

Strategy 1: Carefully design and build astronomy classrooms

Strategy 2: Give each person an astronomical name

Strategy 3: Develop "Galaxy Coin" in class

Strategy 4: Design "Astro Game"

Strategy 5: Carry out a variety of hands-on activities

Strategy 6: Combine mythology, starry sky software, and develop constellation seals to explain the four seasons of the starry sky

Strategy 7: Develop starry sky stage plays

Strategy 8: Invite astronomy lecturers into astronomy classes

Strategy 9: Introduce remote observatory technology into the classroom and enrich classroom teaching

Strategy 10: Extend the astronomy classroom to the outdoors – to use bigger space

New Space Education

Speaker: Ayelet Weizman, Kibbutzim College of Education, Technology and the Arts, Israel

The “New-Space” era provides many opportunities for widening the meaning of astronomy education. In this contribution, my perspective and experience as a Space Educator are described, and some examples, from a M.Ed. in EdTech track centered on Innovation and Space Education, located in a College for Education in Israel are presented. The participants in this track are mainly K-12 teachers in various subject matters. Our vision is that space can be used as a context, inspiration, and example for teaching any subject matter, for the integration of innovative technologies in teaching, and for teaching 21st Century skills, like problem solving, collaborative-learning, critical thinking and agility. I have discussed some students’ action-research examples of learning-units that they developed for their own students.

Talk link: https://youtu.be/R4tAiQV3mlI

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The “New-Space” era provides many opportunities for widening the meaning of astronomy education. It is no longer restricted for outstanding individuals but becomes relevant for a wider audience. The “players” in the space sector are no longer superpowers, but also private companies, associations, and entrepreneurs. The people who get to experience a space journey are not only professional astronauts, but also ordinary people, space-tourists, with varied ages, professions, ethnicities. When teaching and learning about space, we should add many aspects that were not emphasised before, like Space-Entrepreneurship, Space-Design, Space-Laws, Space-Psychology, and Space Tourism. Therefore, I suggest replacing the term “Astronomy Education” with “Space Education”, conveying the message that space is related to everyone, and anyone can be part of it.

In terms of curriculum design, I see Space Education as a spiral cross-curricular topic, intertwined with technology. The goal of the educational system is to prepare students to cope with future challenges. Space can be seen as a context for such challenges, and as the source of many examples of how to use technology to overcome challenges.

Many countries have adopted the concepts of Computational Thinking together with Digital Literacy as part of their curriculum. In my view space can serve as the perfect context for teaching these concepts. In addition, Space Missions provide wonderful examples for engaging in constructivist-based pedagogies, like PBL (Problem- or Project- Based Learning), IBL (Inquiry Based Learning), DBL (Design Based Learning) etc.

This approach is applied at Kibbutzim College of Education in Israel, as the rationale for a M.Ed. in EdTech two-years track called “Innovation, Space and Robotics". The participants in this track are mainly K-12 teachers and informal educators, graduated in various disciplines, and teaching

Elementary School			
Grade	Topic	Skills	Technology
K-2	Basic space concepts	Reading Digital Literacy	Digital games
4-5	The Solar System	Problem Solving, Computational Thinking	Robots (Thymio)
5-6	Earth & Planetary Surface formations	Problem Solving, Computational Thinking	Robots (EV3)
Middle School			
Grade	Topic	Skills	Technology
6-8	Analog Space Inquiry interdisciplinary topics in 3 main aspects: Environmental, Human, Technology	Inquiry skills Teamwork Problem Solving	Sensors Robots

various grade levels. Our vision is that Space can be used as a context, inspiration, and example for teaching any subject matter, for the integration of innovative technologies in teaching, and for teaching 21st Century skills, like problem solving, collaborative-learning, critical thinking, and agility.

For their final project, students in this track engage in action research to study an educational problem from their own experience. The studies are related to either space, robotics, or other aspects of innovative technology in education.

As a result of two years of studies, a partial outline for a New-Space Curriculum shown in Table 1 has emerged.

Some findings from students' action research:

- Young students can understand concepts about motions in the Sun-Earth-Moon system.
- 5th grade students' engagement and motivation in learning increased through participation in a unit based on space & robots.
- Teachers who had no background in space and computing designed effective units after studying computational thinking in space contexts.

Conclusions: "New Space" brings new challenges and opportunities that require a new approach to curriculum development. I suggest including space as a context intertwined with technology as a cross-curricular topic. Our students' action research studies indicate that through application of innovative pedagogical approaches (like PBL, DBL, IBL etc.) students will develop competences and skills to cope with future challenges.

The Role of OAE Center Egypt in Astronomy Education and Developing Curricula for the Pre-University

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

The education of astronomy in the pre-university levels represents one of the most important challenges in our societies where astronomy has not been linked with basic sciences as required or appropriately. By evaluating the curricula of astronomy in pre-university levels, we found a large gap between these curricula and scientific facts and recent discoveries about the universe. With the beginning of work at the Astronomy Teaching Center in Egypt and Arabic-speaking countries the work has been done to evaluate science curricula for early stages of education, the missing topics were collected and work in parallel to provide complementary scientific materials.

Talk link: `https://youtu.be/Nb9tEgu9isA`

The OAE Center in Egypt hosted at the National Research Institute of Astronomy and Geophysics NRIAG, Helwan, Cairo Egypt. NRIAG is considered a beacon of astronomy education, awareness and outreach in Egypt, North Africa and the Arab region. NRIAG plays an essential role in this respect on an academic level through its different facilities of expert staff and resources.

The OAE Center Egypt contributes and supports the education of astronomy at early stages, by working in parallel on five axes:

1. Curriculum development: cooperation with the Ministry of Education and search together with experts on ways of cooperation to contribute to the development of curricula.

2. Organising training courses and workshops: to qualify teachers for teaching astronomy in a practical way.

3. Producing educational materials: writing Arabic booklets and books to simplify the teaching of astronomy, and designing models to explain modern astronomical topics in a simplified manner.

4. Translating educational materials: as language is considered a barrier that prevents many teachers and students from deepening their knowledge of astronomy and making it available to them.

5. Strengthening the role of the center at the regional level in the Arabic speaking countries through the regular interaction of the OAE Center Egypt with the NAEC teams in the Arabic speaking countries.

OAE Center Egypt goes through these axes via five steps.

1. We worked on evaluation of the astronomical topics in the curricula from ages 6-12, 13-15 and 16-18. In summary we found missing knowledge about basics and recent developments and discoveries about the cosmos.

2. We produced a number of simplified books about some astronomical topics, designed some astronomical models and developed a number of astronomical cards.

3. We organised the training courses and workshops for students and teachers.

4. We introduced astronomical concepts following different astronomical phenomena.

5. In the Arabic region we organised a workshop with NAECs and NOCs of Arabic countries to discuss the challenges and ways for cooperation in developing astronomy education at the early stages of education.

Fulldome Curriculum of Astronomy Lessons for Primary School Students in the Dome Theater of China Science and Technology Museum

Speaker: Zhao Ranzi, Technology teacher at the China Science and Technology Museum, China

China Science and Technology Museum has a 30-meter dome with a digital & optical astronomical demonstration system. Since 2018, we have developed 10 lessons on different topics for primary school students and families. Each lesson lasts about an hour. Students can not only enjoy the starry sky at any time and place, special celestial phenomena such as eclipses and meteor showers, but also fly over different celestial objects at close range. Curriculum helps students understand planetary orbits and the three-dimensional structure of the universe intuitively. Some lessons have been shared with several planetariums. In the next step, more lessons will be developed, and more teaching plans will be designed according to the cognitive level of students at different ages to serve more students.

Talk link: https://youtu.be/ss49m--2DG8

In this contribution we share the basic situation and development experience of our "Dome Theatre Feature Astronomy Class" in the dome theatre of the China Science and Technology Museum.

The China Science and Technology Museum is the only national comprehensive science popularisation venue in China, with a 30-meter diameter dome theatre. In 2018, the theatre's digital astronomical demonstration system was upgraded to use Digistar 6 software from Evans & Sutherland in the United States and 10 high-brightness laser engineering projectors from NEC in Japan. Using the powerful database and demonstration functions of the revamped system, we have developed 10 sets of interactive astronomy lessons, mainly for primary school students.

Through research and analysis, we determined that the main audience of the course is primary school students. For this group, we mainly consider two problems when designing the course: on the one hand, according to Piaget's theory of cognitive development, due to the limitation of cognitive development level and spatial imagination, students have certain difficulties in understanding the knowledge content in the field of astronomy; on the other hand, for students who live in cities for a long time, there are fewer opportunities to directly view the starry sky, but with the improvement of living standards year by year, and in recent years, China has made great progress in the field of astronomy and space exploration, and the society generally has a greater demand for astronomy and aerospace science.

In terms of specific curriculum development, we mainly share three aspects. First, in the selection of course topics, from the traditional conventional astronomical content, such as constellations, the solar system, etc., to important celestial phenomena, astronomical frontier discoveries and hot events at key nodes of aerospace engineering. Second, in terms of content details, we refer to the "Science Curriculum Standards for Compulsory Education" (2022-year edition), focusing on the existing knowledge points of school education, based on the core concepts of 13 subjects, reorganising the curriculum content, and focusing on the teaching of interdisciplinary knowledge. Third, in teaching and expression, we pay attention to integrating core qualities such as scientific concepts, scientific thinking, inquiry practice, and attitude responsibility into the curriculum. Using the unique display characteristics of the dome, we can enhance students' immersive experience, and display abstract astronomical content concretely to stimulate students' curiosity and imagination.

Since 2018, we have conducted 30 courses with more than 5,000 participants. Courses have been shared with several provincial and municipal science and technology museums and planetariums. In the next step, we will develop and design courses according to the cognitive level of students of different ages to serve more students.

Development of a Non-Formal Education Curriculum in Astronomy for Middle School Students

Speaker: Avik Dasgupta, Vikram A. Sarabhai Community Science Centre, India

School Science Forum is a non-formal education course conducted at Vikram A. Sarabhai Community Science Centre for middle school children (standards 5–9) in Ahmedabad, India. As part of this, the astronomy lab has developed a curriculum so that we can gradually introduce students to the basic concepts of astronomy. The sessions are based on short lectures supported with hands-on learning, model making, observations, and discussions. The concepts included are moon phases, constellations, circumpolar constellations, day time astronomy & sundial and understanding & making a telescope for students from standards 5–9, respectively. Here we have discussed the development and various learnings from these sessions.

Talk link: https://youtu.be/Sx6s8WUWkCA

Vikram A. Sarabhai Community Science Centre (VASCSC), a pioneering institute with open labs was founded by eminent space scientist Dr. Vikram Sarabhai in 1966. School Science Forum is a non-formal education course conducted at VASCSC for middle school children (standards 5–9) in Ahmedabad, India. As part of this, the astronomy lab has developed a curriculum where the students are gradually introduced to the basic concepts of astronomy. The sessions are based on short briefings supported with hands-on learning, model making, observations and discussions. The details of each topic, related session, hands-on activity, and astronomical concepts covered standard-wise are tabulated below.

The curriculum was designed to be in parallel with the National Council of Educational Research and Training (NCERT) text books' concepts. In each session, we start from a daily life phenomenon and slowly bring in the related astronomical concepts, aided by hands-on activities and observations. Our content is standard appropriate, we gradually introduce a deeper level of content as students move to higher classes. We try to leave them with common answers and a lot more questions to ponder on. And finally inspire them to wonder about the universe and uniqueness of our Earth.

Standard 5

Topic(s)	Session	Activity	Astronomical Concepts Covered
Moon Phases	Moon Phases	Template based Moon Phases	New Moon and Full Moon; Period of rotation and revolution of Moon around Earth; Phases of Moon; Eclipses; Observations for next moon phase cycle

Standard 6

Topic(s)	Session	Activity	Astronomical Concepts Covered
Constellations	Constellations	Joining the stars to make a constellation chart	Identifying Constellations for a given time period; Drawing them and understanding the folklores behind them; Difference between constellation, asterisms and zodiacs; How zodiac leads to prediction and pseudoscience

Standard 7

Topic(s)	Session	Activity	Astronomical Concepts Covered
Circumpolar Constellation	Circumpolar Constellation	Template based Circumpolar Constellation clock	Review of different constellations; Seasonal and circumpolar movement of constellations; Difference of circumpolar movement in different hemispheres and latitudes using video; No pole star at southern celestial pole; Changing pole star due to precession; Accompanied by night sky observation, identification of constellations and night sky software.

Standard 8

Topic(s)	Session	Activity	Astronomical Concepts Covered
Solar astronomy	Sundial and sunspot observation	Template based horizontal Sundial	Introduction to Solar Astronomy; Sun daily, seasonal and yearly motions; Making horizontal sundial, understanding and observing; Sunspot Observation
	Sun projector	Making and observing Ball Mirror and understanding the rotation of Earth	Making a Ball Mirror and projecting the Sun's image to observe Earth's rotation; Understanding Sun as a star; Physics behind sun spots; Repeating Sunspot Observation and discussing the changes in spot positions

Standard 9

Topic(s)	Session	Activity	Astronomical Concepts Covered
Telescopes & beyond	Refractor Telescopes	Making Objective Box	Introduction to reflection and refraction; Working of refractor telescopes; Demonstration and handling refractor telescopes; Types of Mounts
	Reflector Telescopes	Making Eye-piece Box, assembling and calibrating	Different reflectors, i.e., Newtonian, Cassegrain, Coude; Demonstration and handling reflector telescopes; Resolution, Magnification and different filters
	Different windows of astronomy and path forward	Glimpse of data sets from different archives	Different windows of Electromagnetic Waves; Ground based and space-based observatories; Gravitational Wave Observatories; Future path ways to pursue astronomy; Staying connected with astronomy – citizen science projects

Developing and Practising Astronomy Curricula for Students Aged 5-6

Presenter: Stella Yang, China West Normal University, School of Physics and Astronomy, Nanjing, China

To explore how to develop a kindergarten astronomy curriculum suitable for Chinese children, we conducted a year-long school-based astronomy curriculum development and practice in a public kindergarten in Sichuan. Initially, we researched the national policy and the cognitive situation of astronomy in this early childhood class. We chose the eight solar system planets as the theme, incorporated the teaching concept of hands-on learning, and used handicrafts and games as the main activities and knowledge transfer as the support. After the development, we started a weekly 90-minute course practice for six months. It has been proved by practice that the course content "The Eight Planets" developed by us is very suitable as an enlightenment course for young children.

Poster link: https://astro4edu.org/siw/p83

To explore how to develop a kindergarten astronomy curriculum suitable for Chinese children, we conducted a year-long school-based astronomy curriculum development and practice in a public kindergarten in Sichuan. We chose to work with children aged 5-6.

Our team consisted mainly of astronomy majors but also included early childhood education and art students. We hired experts in early childhood astronomy education to review the content of the curriculum to ensure the correctness of the knowledge and to enhance the artistry, inspiration, and fun of the curriculum.

In the early stages of development, we researched the national policy and the cognitive situation of astronomy in this early childhood class. We determined the content and teaching format of the curriculum. We chose the eight solar system planets as the theme, incorporated the teaching concept of hands-on learning, and used handicrafts and games as the main activities and knowledge transfer as the support. After the development, we practised the curriculum for six months, once a week (90min). Based on the feedback from children, teachers, and parents, we iterated and modified all the classroom contents, hoping to form a series of astronomy courses that can be universally applied to any kindergarten.

The content we developed, "The Eight Planets" has proven to be a perfect introduction to astronomy for young children. Astronomy is an ideal subject for science initiation. It is not only related to life but also intersects with many disciplines and can open the door to science for children.

In the future, we will also devote ourselves to develop astronomy enlightenment content for young children, expanding from schools to families and science museums so that each child's small universe and the entire universe can be connected and a complete astronomy enlightenment education for young children can be realised.

Exploring the Universe in El Salvador for Public from 4-years Old

Presenter: Brisa Terezón, Micro Macro Observatory - Don Bosco University, El Salvador

We present the experience of developing workshops aimed at the public from 4-years old. The subjects of astronomy and microscopy were selected from the educational curriculum of El Salvador. For astronomy topics, we use teaching materials suggested by NASE. As for microscopy, the experience of Botanika in Bremen was taken as a basis. The workshop includes observations of the universe with microscopes and telescopes, to show in a practical way how small-scale universes make up large-scale universes.

Poster link: https://astro4edu.org/siw/p84

This workshop was developed by Micro Macro Observatory, located at Don Bosco University. The workshops' objective was exploring the universe on a small and large scale. The workshop includes observations of the universe with microscopes and telescopes, to show in a practical way how small-scale universes make up large-scale universes.

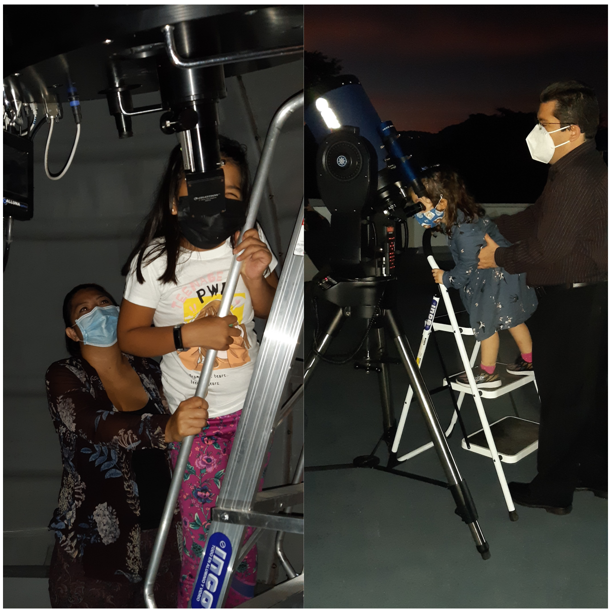
The subjects of astronomy and microscopy were selected from the educational curriculum of El Salvador, which include constellations, solar system, Earth, and Moon for the astronomy part. On the other hand, the main experiment with the microscope is the observation of onion cells (https://www.mined.gob.sv/guia-de-programas/). For astronomy topics, we use teaching materials suggested by NASE (Network for Astronomy School Education). As for microscopy, we used the experience of Botanika in Bremen, Germany to introduce children to the micro universe using a magnifying glass and microscope.

The main astronomy topics in our workshop were stars and constellations, solar system, solar and lunar eclipses, astronomy of position, star evolution, galaxies, and cosmology. About the telescopes, the activities were: main parts of a telescope, installing the telescope, types of telescopes, observing the sun, stars, moon, planets, and galaxies. The activities for microscopy were observing the flower garden, the microscopic world in the apple and exploring the Earth's rock.

The workshop was offered for public from 4-years old. We had 55 participants. The youngest was a four year old and the oldest was 74 years old. We used 10 hours to do hands-on activities and 10 hours for astronomical observations with naked eyes, microscope and telescope.

Micro Macro Observatory

Children using microscope



Children observing the Moon and planets using a telescope

Astronomy Education in Curriculum of Nepal

Presenter: Raj Kumar Dhakal, Science Teacher, Gandaki Boarding School, Pokhara, Nepal

The curriculum of Nepal is being prepared, updated and evaluated by the Curriculum Development Centre (CDC) under the Ministry of Education, Science and Technology in Nepal. Generally, the curriculum is being updated every 10 years and Nepal is in the phase of implementation of a new curriculum, which was prepared in 2022. As per the new curriculum astronomy is included under Science and technology from Grades 4 to 10 and Physics in Grades 11 and 12, and astronomy is not a stand alone subject, thus given less priority. One of the reasons for this could be the less interest of teachers and curriculum developers in astronomy education. With the new curriculum in place, there is a need for capacity building among the teacher and educators to facilitate the understanding of the knowledge along with the newer updates in the introduction of chapters and units in the astronomy in Nepali science books/curriculum.

Poster link: `https://astro4edu.org/siw/p88`

Although astronomy is a separate branch of science it has been included as a physics curriculum in Nepal. The curriculum of Nepal is being prepared, updated and evaluated by the Curriculum Development Centre (CDC) under the Ministry of Education, Science and Technology in Nepal. Generally, the curriculum is being updated every 10 years. According to the policy, Nepal is currently in the phase of implementing the new curriculum, that was prepared in 2020. The new curriculum was implemented for Grades 1, 6 and 11 in the year 2020, for Grades 2, 3, 6, and 12 in the year 2021, for Grades 4, 7 and 9 in the year 2022 and for Grades 5, 8 and 10 will be implemented in the year 2022. As per the new curriculum of Nepal prepared by CDC, astronomy is included under the curriculum of Science and technology from Grades 4 to 10 and Physics in Grades 11 and 12.

Looking at the scenario, our curriculum gives less priority to astronomy education. One of the reasons for this could be the little interest from teachers, educators and curriculum developers in astronomy education. In spite of this, astronomy education is being included in each level now as a major unit.

The inclusion of astronomy in curriculum is divided into following points:

1. Basic level (For classes 4 and 5)
   Earth and Space: The topics are related to Structure of the earth, Various spheres of the earth, Weather and climate, Weather forecasting, the sun, the moon and the earth including revolution and rotation of the earth and moon, Phases of the moon, etc.

2. Basic level (For classes 6 to 8)
   Earth and Space: Soil, Rocks and Minerals, Soil profile, Layers of the earth, Season change on the earth, the sun and the Solar system, Phases of the moon and Lunar Calendar, Eclipse and causes, Universe, Asteroids, Comets, Constellations, Galaxies, Meteors and Meteorites, Evolution of the living organisms on the earth.

3. Secondary level (For classes 9 and 10)
   Astronomical units, Nebula and black hole, Life cycle of star, National/ International agencies working in astronomy, Importance in gravitational force, Origin of the Universe according to Big bang theory, Conclusion of Hubble's law, The future of universe on the basis of gravitational force.

Astronomy in Brazilian Basic Education: a Look at BNCC of Elementary School

Presenter: Thais Alexandre, Universidade de São Paulo, Brazil

Collaborators: Taynara Nassar and Cristina Leite (Universidade de São Paulo, Brazil)

Astronomy is present in the Common National Curriculum Base in Brazil. The analysis of this document enabled us to build an overview of the themes related to astronomy in elementary school. It was possible to perceive that there is an indication for proposals of sky's observation, with identification of heavenly bodies and comprehension of the movements of the Earth, Sun and Moon, as a way of understanding periodic phenomena on the first cycle of elementary school. In the second cycle, the focus is the construction of relations between sky's observations and scientific models, enabling the construction of arguments, interpretations and justifications based on scientific evidence for these phenomena, in addition to deeper studies about the dynamics of the heavenly bodies of the Universe.

Poster link: https://astro4edu.org/siw/p85

Astronomy is one of the oldest sciences, being present in several situations everyday, and reference for aspects such as time counting, agriculture, and others (Caniato, 2011). The subject has been present in the brazilian curriculum since colonial time (Leite et al., 2014) and remained nonlinear in the following century, even in context of change and curricular reforms (Hosoume et al., 2010).

The current Brazilian curriculum document, the Common National Curriculum Base (BNCC, in portuguese), presents science thematics in competency format, abilities and knowledge objects such as learning rights by school levels and/or years. The astronomy thematics are more explored in the curriculum component science, in the thematic unit Earth and Universe (Brasil, 2018). Astronomy is present in all basic schools, and its themes are expressed by abilities and proposals that involve the understanding of Earth, Sun, Moon and others heavenly bodies, sky observations, and cultural astronomy, for example. This summary presents an analysis of these actions expressed by the verbs in astronomy's abilities and verifies how they develop throughout elementary school.

Methodology: The analysis was made from a reading of BNCC, specifically of the science part from elementary school, which identified the abilities that have a direct relationship with astronomy knowledge objects and the associated verbs. The verbs were analysed qualitatively, and are associated with the framework of scientific research processes and practices listed in the BNCC, which divides them into stages: problem definition; survey; analysis and representation; communication and intervention (Brasil, 2018, p. 323).

Analysis and Results: The analysis allowed us to identify that the astronomy's abilities propose action related with practice, process and scientific investigations procedures, as proposed in the document. The application of these actions is convergent with the proposal too, to promote learning and more distributed learning throughout elementary school.

It is possible to identify the presence of contents marked by experimental processes and sky's observations on the first cycle, related to the defined problem, interpretation and construction of argumentation. On the second cycle, the verbs indicated proposals with greater emphasis on deepening, expanding the world view through the articulation between different points of view, and can also be related to stages of analysis, representation and communication. It is noted that verbs related to the communication and intervention stages are less present in the skills analysed. Understanding the dynamic of teaching and learning that is proposed is fundamental to think and rethink the practice of teaching astronomy in the classroom, the organisation of didactic material based in the curriculum distribution proposal and for the initial and continuing training of science teachers for basic school.

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“Colonization of Mars – Challenges and Solutions” – a Game-Based Activity

Presenter: Eleana Balla, NOESIS - Thessaloniki Science Center and Technology Museum, Greece

Educating people on astronomy and space science can act as a "gateway" that opens a world of possibilities by nurturing inquisitiveness and the pursuit of knowledge using the scientific method. Moreover, as astronomical research is technology driven, astronomy and space education provide excellent opportunities to enhance different aspects of STEM education. NOESIS being inspired by the human’s plan to colonise Mars developed the game based activity "Colonisation of Mars-challenges and solutions" for secondary students. Using tablets and an android app the students are dealing with challenges and situations faced by scientists, experts and astronauts in the colonisation project of Mars.

Poster link: `https://astro4edu.org/siw/p86`

Science, Technology, Engineering and Mathematics (STEM) play an important role in contemporary society. They shape an area that transformed our lives and is continuing to evolve and determine our world, building the sustainable society of the future. In such a society, computational, social and cultural skill as well as creativity, critical thinking and problem solving are essential for the citizens. While schools and universities are mainly responsible for educating the youth, the non-formal sector plays a critical role integrating science learning and developing 21st century skills.

Educating people on astronomy and space science can act as a “gateway” that opens a world of possibilities by nurturing inquisitiveness and the pursuit of knowledge. Moreover, as astronomical research is technology driven, astronomy and space education provide excellent opportunities to enhance different aspects of STEM education.

In most European countries, there is not a stand-alone educational curriculum of astronomy in the secondary level. On the other hand, in non-formal organisations, such as planetariums and science centers, astronomy and space science are strongly represented, remaining among the most popular topics. In the context of the "Future Space" erasmus plus project, teachers and science centers worked together to develop an astronomy and Space Program for secondary school students. The program contains lesson scenarios that can be performed by teachers in school classes and activities that can be implemented during a school visit to a science center.

NOESIS science center, being inspired by the human’s plan to colonise Mars developed the game-based activity “Colonisation of Mars - challenges and solutions”. Using tablets and through an android app, which has been designed for this activity, the students are dealing with challenges and situations faced by scientists, experts and astronauts in the colonisation project of Mars.

The 90-minute activity takes place in a properly equipped room, facilitated by 1-2 facilitators. Starting with an introduction, a short-guided discussion reveals students' ideas about human efforts to visit and colonise Mars. During the experimentation phase, the students in groups are moving around working stations to perform five different tasks. Each task, which is fully described in a dedicated board, transfers students to a specific place and time, assigns them to a specific role and sets a unique goal. Diverse tools and means (boards, cards, 3D objects, lab equipment, tablets) are used to practice different students' skills. Finally, at the reflection phase, the students discuss in plenary their work and outcomes and scientific information and up to date data from current research are provided.

The elements of Inquiry based learning (essential questions, student engagement, cooperative interaction, performance evaluation, variety of responses) and the elements of Gamification (the tasks determine the goals, the environment represents real-world situations and the students are digitally engaged) are present. Collaborative Learning is also met, as students while working in groups, take on specific roles, try to accomplish certain goals and share ideas, understanding and communication.

The activity is available for school classes visiting NOESIS. During the school year 2021-2022, thirty-five classes and 1200 students participated. An evaluation of the activity by using questionnaires is in progress.

Resources:

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The Strengths and Weaknesses of Astronomy in the Curricula and Some Suggestions that can be Implemented to Advance Astronomy

Presenter: Mostafa Mohamed Mostafa Mohamed, Science teacher at El Salam Preparatory School for Boys in Cairo, Egypt

As a science teacher in Egypt, I would like to share my experiences in science education and astronomy curricula for school students aged 12-15. I will display some points of strengths and weaknesses in astronomy curricula and the methods of astronomy education. I will also give some suggestions, which may help improve the situation.

Poster link: https://astro4edu.org/siw/p87

Strengths:

- In the first year of middle school (second term) students learn about celestial bodies and then learn about our planet Earth.
- In the second year of middle school (first term) students learn about the different layers of the atmosphere and the phenomena associated with each layer.
- In the third year of middle school (first term) students are introduced to the theory of creation of the universe and the theories Of the formation of the solar system.
- Students learn about the existence of life on planet Earth.
- Students identify climate problems and their direct impact on life.
- Students learn about the solar system, planet Earth, and the occurrence of some astronomical phenomena.

Weaknesses:

- The weight of astronomy curricula on the student during the educational process.
- Unavailability of teaching aids, such as planetariums, scientific museums, and augmented reality technologies (simulation).

- Unavailability of real cultural awareness in society of the importance of many sciences.
- Society's feeling that there is no direct financial return from these sciences.
- There are some misconceptions held by many of those involved in the educational process.

Suggestions:

- Providing visitor access at scientific museums for universities and institutes, which will make the educational process more interesting for students and have many benefits as well, such as informing the student of the stages of development of science and technologies.
- Increasing cooperation between scientific research institution and educational institutions to assist those in charge of education to acquire correct concepts that develop from time to time with the development of research.
- A systematic distribution of a curriculum for astronomy.
- A good marketing of astronomy (as is done for some other science branches like medicine and engineering) is important because there are many technologies that society enjoys without realising the role of fundamental sciences like astronomy and the scientists that work on them.
- Providing visual aids such as virtual reality techniques and videos, planetariums, which are provided by many developed countries to assist the educational process.
- "What will we benefit from studying astronomy?" - a question asked to every science teacher. This question can be answered by mentioning the achievements that astronomy contributes to, which facilitate many of our daily operations, such as using the GPS and various communication and broadcast networks.

I think that if the ideas described above are implemented, we will be able to inspire students to learn eagerly, provide them with good educational materials, train the teachers to teach effectively, and build a cultural awareness in the parents and the community in general; these will help the country become more prosperous.

Discussion summary

Developing any curriculum requires one to be highly passionate and motivated about one's* field of study. It also requires students' interest in the subject. In the session discussions, the motivation for the teachers to develop these was based on their love for science and more so, sharing this science with their inquisitive students. Much of the developed curriculum has been improved through the feedback from the students, as our invited speaker has mentioned, 'the motivation was the feedback from students, which made us realise that they are interested regardless of age'. This was not unique to the invited speaker as the sequencing of the content and activities given to students was also based on the feedback from both the teachers and students. This shows that, unlike in the traditional sense, a curriculum can be both a top-down and bottom-up approach, where students' interests can drive the content and the teachers or ministries drive the learning goals.

The contributed talks also shed light on different aspects of developing an astronomy curriculum, including the difficulties of it thereof. For example in many countries, astronomy is not necessarily its own subject, it is rather included as part of the other sciences. Introducing it as a curriculum makes its implementation difficult at times, however, integrating aspects of it in subjects such as Physics, Mathematics, Chemistry, Geography, and technology has been helpful. More so, astronomy has transferable skills that can be used in the learning and teaching of other subjects.

When it comes to technology, we see its potential in astronomy, from telescopes to planetariums, especially in recent years with the introduction of digital planetariums. One of the speakers developed the curriculum in the science museum where they have a three-dimensional theatre, they try to use a three-dimensional model to give the students an immersive, 3D impression in which they cannot demonstrate their ideas. This helps students with understanding difficult astronomical concepts, and the immense dimension of our universe. Overall, developing a curriculum is not only limited to the classroom; planetariums and science museums alike are also a way of developing, but it is important that the curriculum still aligns with the national standards of the country, which are sent out by the Education Ministry.

The implementation of the curriculum and its continuity can only be achieved when the curriculum does not belong to a person but rather is shared with other teachers, developers, and ministries. Once the ministries approve the curriculum, it is implemented by the teachers. However, it is also important to train pre-service teachers on how to teach the new curriculum, so that when the old teachers retire, there are still new teachers that are going to continue with the vision of making their students scientifically literate. It is also important for teachers to be aware of the students' diversity, for example, learning how to cater to students with special needs in their science classroom.

The speakers also discussed the key things to consider when developing and organising the curriculum and its excursion (teaching it). From the training teachers' perspective, the emphasis is on teaching 21st-century skills, which the teachers can use in their classrooms, to keep learners engaged and interested. Using a lot of theory-based methodologies, such as constructivistic approaches, and problem-based learning techniques that are research-based.

Insights from Astronomy Education Research

Astronomy Education Research on the Role of Astronomy in Schools

Session organisers: Emmanuel Rollinde (OAE Node France), Assia Nechache (OAE Node France), Tshiamiso Makwela (OAE Heidelberg), Estelle Blanquet (University of Bordeaux, France), and Merryn Cole (University of Nevada, Las Vegas)

Session overview

This session focused on the impact of Astronomy Education Research on science literacy and practices in schools. Three topics are discussed by the different contributors.

Astronomy education is considered not only as an education to astronomy content but on skills and competencies that may be transferred into other and sometimes more general contexts. Three skills of that kind will be discussed during this session: spatial thinking, quantitative reasoning and critical thinking.

Astronomy education is related to scientific methods and has strong connections to science, mathematics, and engineering. This connection is discussed to investigate how astronomy education may contribute to motivating students into STEAM subjects and careers.

Astronomy education topics are nowadays present in many curricula. This requires specific teacher training in astronomy and yields an overall impact on teachers' professional development. Hence, evaluation and assessment tools of curricula and teachers' professional development have been developed and will be presented in this session.

Developing Transferable Spatial Thinking and Vocabulary Skills Through Astronomy Education

Speaker: Merryn Cole, University of Nevada, Las Vegas, USA

Research has shown the importance of spatial thinking in STEM fields in general and astronomy specifically. Spatial thinking skills have also been shown to be transferable. Since astronomy topics such as the moon phases or daily celestial motion are accessible to everyone, this is an ideal topic with which students can engage and learn or practice spatial thinking skills that can be useful in astronomy as well as across and beyond STEM fields. I discuss recent research showing how implementing a spatially-rich, lunar phases-focused curriculum improves both student understanding of moon phases as well as spatial thinking ability. Additionally, this curriculum has been shown to improve students' scientific vocabulary more than a typical astronomy curriculum used as a comparison.

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

Research has shown the importance of spatial thinking in STEM fields in general and astronomy specifically (e.g., Pribyl & Bodner, 1987; Wilhelm et al., 2013). Since astronomy topics such as the Moon phases or daily celestial motion are accessible to everyone, this is an ideal topic with which students can engage and learn or practice spatial thinking skills that can be useful in astronomy as well as across and beyond STEM fields. Spatial thinking is the perceptual and cognitive processes that allow humans to create and manipulate mental representations of the spatial properties of objects, structures, and systems. It also includes the capacity to use external representations or internal representations, like mental models, to make inferences or solve problems about the spatial properties of these same things (Cole, Cohen, Wilhelm, & Lindell, 2018). Spatial thinking is correlated with understanding of STEM content, including astronomy (Pribyl & Bodner, 1987; Wilhelm et al., 2013) and is also predictive of both participation in STEM and of earning higher level achievements, such as earning a PhD vs a BS, in STEM (Kell, Lubinski, Benbow, & Stanley, 2013; Uttal & Cohen, 2012).

We used a hierarchical linear model (HLM) to investigate how well a project-based unit (PBI) helps to improve students' understanding of lunar phases. We asked four research questions: After instruction, did a student with a higher Lunar phases assessment score also tend to have a higher spatial assessment score? Before and after instruction was an increase on assessment associated with an increase on the other? Was the unit effective in improving student learning of lunar phases? And among measures of student demographic characteristics, their spatial ability of rotating irregular objects, and contextual factors from their teachers, what were those that significantly predicted their content knowledge of lunar phases? We gave two assessments to both teachers and students prior to and after instruction. First was the Lunar Phases Concept Inventory (LPCI), which is a 20 question multiple choice assessment that measures students understanding of lunar phases (Lindell & Olsen, 2002). Second was the Purdue Spatial Visualisation Test of Rotations (PSVT-Rot), which is a 20 question multiple choice assessment that measures students spatial ability, specifically mental rotation (Bodner & Guay, 1997). We also provided professional development to teachers about the unit where we included content knowledge as well as how the lessons were designed and why. The unit we used is called Realistic Explorations in Astronomical Learning, or REAL for short (Wilhelm, Wilhelm, & Cole, 2019). A couple of things to highlight in this unit. We use moon journals for about 4-5 weeks, where students not only record the appearance of the moon, but they also record the location of the moon and write to learn. The writing is focused on patterns they notice as well as making sense of what they are observing. Another lesson is related to the scale of the Earth, Moon Sun System, which is essential in understanding Moon phases. Finally, the last lesson asks students to use foam balls and a light to model Moon phases. One thing that makes this lesson different from similar modelling activities is that we have students refer to their Moon journals, to help them self-correct as well as to connect their real-world observations to the classroom modelling.

We found students' lunar phases score was correlated with their spatial score. Similarly, we found that students' increase in lunar phases understanding was associated with their increase in spatial thinking ability. These are both what we expected, based on previous research showing that lunar phases understanding and spatial thinking ability are significantly correlated (e.g., Wilhelm et al., 2013). We used a hierarchical linear model in order to investigate the factors that impact students' lunar phases understanding. The final model predicted that on average, students would increase their scores by 14.8 points from pre- to post-instruction. This again was not a surprise, as previous research has shown REAL to be effective in improving both students understanding of lunar phases and their spatial thinking ability. As far as significant predictors, we were surprised to find that gender was not significant. In the literature, typically boys are better at spatial thinking than girls. Students from two race/ethnicity groups (Hispanic American and Other, both self-reported categories) performed significantly worse than their white classmates. We suspect this could be related to things like language. If some of these students were English language learners, for instance, we would not be surprised if they struggled with instruction or the assessments. Student spatial score was a highly significant predictor of lunar phases scores, which again was not surprising to us as it agrees with previous research. Finally, the most interesting piece was that teacher GSV (geometric spatial visualisation) score provided highly significant explanatory power of student lunar phases performance. GSV is one of the four spatial domains that we can categorise the lunar phases assessment questions into (Wilhelm, 2009). GSV refers to considering the system from above, below, or within the plane of the system. While teachers cannot teach content they don't know or understand, similarly it makes sense that if teachers have not developed their own spatial thinking ability or understand its importance, it would be difficult or for them to foster spatial thinking in their students.

Since we know that spatial ability is important and can be improved, we should be developing and using units like REAL that develop transferable spatial skills and vocabulary to potentially increase participation in STEM careers. Sadly, spatial ability tends not to be emphasised in schools, at least not in the United States, which "not only prevents less able students from achievement in science. It also hinders us from identifying and nurturing the talents of our most spatially able students" (Hegarty, 2014, p. 143). So, the way I interpret this is that if we want to address the leaky STEM pipeline, fostering the development of spatial skills may be one way to do it. And part of patching that leaky STEM pipeline through spatial thinking involves working with teachers to develop their spatial thinking and also helping them to understand the importance of spatially rich lessons for their students.

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Infusing Quantitative Reasoning into Introductory Astronomy and Other Science Courses

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

Collaborators: Kate Follette (Amherst College) and Erin Galyen (University of Arizona)

Quantitative reasoning (QR) is a skill important not only in school but in everyday life. We describe an ongoing effort to understand students' quantitative reasoning skills and beliefs and how quantitative reasoning is supported in introductory astronomy and other science courses. We will share ongoing results of a study utilising the Quantitative Reasoning for College Science (QuaRCS) assessment, a QR assessment designed for use in general education science courses, as well as ongoing work to make items more culturally relevant. Additionally, we will discuss work to support instructors in infusing more quantitative reasoning into their courses.

Talk link: https://youtu.be/Th4B3qLuu00

We report on an ongoing study investigating students quantitative reasoning that include skills important for school and everyday life. At the center of this effort is the Quantitative Reasoning for College Science assessment (QuaRCS). The development and validation of the QuaRCS instrument is described in Follette, et al. (2015) and Follette (2017). The full QuaRCS instrument includes 25 items and there is a shorter QuaRCS "light version" that has 15 items. The QuaRCS assessment assesses undergraduate students' knowledge of basic quantitative skills, attitudinal and affective variables, as well as some context variables, including academic background and student demographics. Students are also asked to report the amount of effort they put into answers on the assessment.

The QuaRCS is designed to assess numeracy, quantitative literacy and quantitative reasoning. All of the items on the QuaRCS are multiple choice. The top five skills within these domains on the assessment are graph reading, table reading, arithmetic, estimation, and proportional reasoning. These are important skills for students in their everyday lives. These are skills that are interdisciplinary and can be included in any introductory science course.

Regression analysis has revealed several factors that account for variance we see in student quantitative reasoning scores. Our early work revealed that effort accounted for a substantial portion of the variance in students' scores. Students who said they were randomly answering did much worse on average on the assessment than students who reported that they tried their best. There were three other factors that accounted for substantial variance in student quantitative reasoning scores on the QuaRCS. These included math relevance, math anxiety, and numerical self-efficacy. Everything else, including student demographics, accounted for very little variance in students' quantitative reasoning scores. More recently, we have started

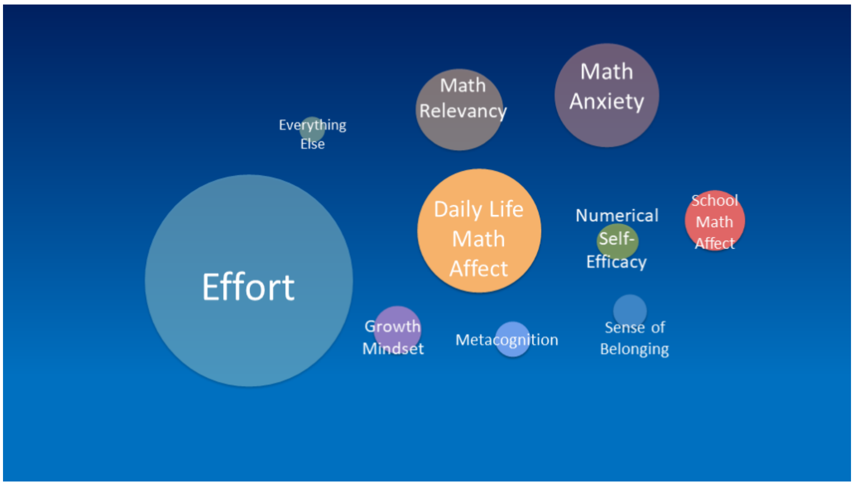

Figure 1: Revised Affective Model of Predictors for Students Quantitative Reasoning Scores

working on new items and updating the model of predictors of students quantitative reasoning scores. In the updated model, see Fig. 1, you can see the relative amount of variance accounted for by different predictors. Effort accounts for a lot of the variance in scores. Math relevancy and math anxiety are also important. Our recent work has shown that what we previously called numerical self-efficacy is made up of other important factors including daily life math affect in school math affect as well as growth mindset, metacognition, and sense of belonging. This revised model is helping us better understand what predicts students' performance and to start to think about how to better support students.

Most recently, we have been working to increase the cultural relevancy of the QuaRCS assessment. This past year, we included questions to the assessment that asked students to report how confident they were in their answer along with a question to asked them to report how the context of the questions resonated with who they were, their reality, lived experience, or things that they cared about. This data, along with data from focus group interview was used to revise items to better align with students' realities and to be more relatable for more students. An example of an item revision can be found below.

Original item: You purchased 100 square feet of solar panels for your roof. However, your local Homeowner's Association requires that solar panels not be visible from the road. You decide to put solar panels on the roof of your shed instead. The shed has a flat 5 foot by 5 foot roof. Complete the following sentence: "To produce the same amount of power as your original design, you need to buy panels that produce _____ more power per unit area than your original panels."	**Revised item:** You are a solar panel installer. A client requires 100 square feet of your standard solar panels to power their home. However, your client wants the panels installed only on a shed in their backyard where they cannot be seen from the road. The shed has a flat 5 foot by 5 foot roof. Complete the following sentence: "To produce enough energy to power your client's home, you need to find panels that produce _____ more power per unit area than your standard solar panels."

When we look at the overall study, we have a few take home messages. We know from our studies and others that negative attitudes towards math is a persistent issue in college classrooms, something as instructors we all need remain aware of. We also know that students' attitudes towards math are more predictive of students' quantitative reasoning scores than any background characteristics. Attending to affective variables diminishes achievement gaps that might have been attributed to student background characteristics. We are still working to figure out how students' demographics are related to different affective outcomes.

We know that introductory astronomy, as well as other science courses, are places to change attitudes, and we believe that these are places to change overall quantitative literacy skills. We are carefully considering how to help students reduce math anxiety, improve students' self efficacy, and hopefully see the utility of math in our courses. We believe that these types of interventions will be helpful for all students.

Our upcoming work will be testing the revisions of the new cultural relevancy items to see how well they perform with students from a variety of backgrounds. In the future, we will be supporting faculty learning communities to talk about how to best support students in developing quantitative literacy.

We invite you to get involved. If you would like to administer the QuaRCS in your undergraduate class, please reach out to Kate Follette kfollette[at]amherst[dot]edu. As an instructor, you will receive pre and post semester reports about how your students are doing in aggregate that summarises your students' skills and attitudes.

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Astronomy Teacher Training Programs in Chile

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

Collaborators: Maximiliano Montenegro (Universidad de La Serena, Chile), Alejandra Meneses (Pontificia Universidad Católica de Chile), Stephen Pompea (NOIRLab)

We show the main results of a questionnaire characterising the professional development programs offered to K12 teachers in Chile in the last five years. Leaders from 16 programs answered on aspects of their planning, implementation, and evaluation, allowing us to outline a profile. We contrast the results with the literature on teachers' professional development programs' effectiveness and discuss the Chilean programs' strengths and aspects to improve. We highlight that most of them are successfully in focusing on curricular topics and offering hands-on activities. However, not many programs evaluate their effectiveness, and almost none follow up with the participant teachers in their subsequent professional practice.

Talk link: `https://youtu.be/dfDMZAi4vFE`

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Chile is home to most of the world's largest telescopes, and accordingly, significant astrophysics research is performed within local institutions [1]. However, although Chilean people value their skies as a national attribute, only 30% of them declare having some astronomical knowledge [2]. Likewise, PISA science evaluation results place Chile lower than the OECD countries' average on the global scale and in the Earth and Space sub-scale [3].

In these conditions, there has been a public interest in enhancing Chilean astronomy education so that, over the last years, local institutions have been offering more such activities, especially professional development (PD) programs for teachers [4]. Nevertheless, there is no systematisation of these programs and no study evaluating their impact beyond reporting the number of participants and their satisfaction.

Furthermore, in previous research, we found that Chilean primary school teachers who participated in astronomy PD programs do not have higher content knowledge than those teachers with no previous training [5]. Thus, it is of utmost interest to trace a profile of the recent astronomy teacher training programs offered in Chile and deliver empirical evidence to institutions so they can achieve more effective and impactful programs.

Method: We conducted an extensive online search and found 20 astronomy PD programs offered in Chile in the last five years. Of these, 16 agreed to participate in this study. During 2021 and 2022, these programs' leaders answered PDPAP (Questionnaire on Professional Development Programs in Astronomy offered for Teachers, in Spanish), an online survey with 41 items, mainly multiple-choice. PDPAP considers the main characteristics of an effective PD program from the literature [6,7,8,4] regarding aspects of their planning, implementation, and evaluation, allowing us to trace a profile of what has been offered to teachers, and identify these programs' strengths and features to improve.

Main results: The 16 surveyed PD programs started from 2009 to 2021, were executed from 1 to 30 times and were offered in all Chilean regions, especially in the North (observatories' location) and the Center (around the capital Santiago). They were mainly organised by astronomy departments within universities (31%), international observatories, and non-formal education centers (both 19%) and were mainly in an in-person format, changing to virtual during the pandemic. The programs were predominantly funded by observatories (35%) and the Chilean National Research Agency (29%) and are generally free of charge for the participants. They were mostly executed during teachers' vacations or weekends (44%), and most were concentrated over a short period, such as one intensive week.

The number of participants per edition ranged from 6 to 100, summing almost 5000 participant teachers within all programs and editions. 12.5% of the programs were offered only for primary education teachers and 19% for secondary education. Alternatively, 56% were offered for teachers from both levels, and in 58% of these cases, they attended classes together. As for duration, the programs ranged from 2 to 40 hours, being distributed in three types: 2 to 8 hours duration (37.5%), 12 to 20 hours (37.5%), and 30 to 40 hours (25%). The programs with longer duration were mainly offered by universities; observatories and non-formal education centers tended to offer shorter programs.

Concerning the contents, the programs offered a wide variety of astronomical topics. All included at least three topics per edition, and many included six or more, except one exclusively about stars. Even most short-duration programs included several topics in the same edition. Most programs chose content aligned with the national curriculum (62%) and reported reviewing curricular documents when planning the classes (87%). Also, 75% of the programs reported addressing misconceptions associated with their astronomy topics, and 87% reported including pedagogical content.

As for learning methodologies, all programs offered traditional lectures and classroom discussions, and most included practical classes, group work, and the use of hands-on resources (75%). Telescope observation, visiting astronomical centers, or working with real data were also common practices, except in the shorter programs. However, methodologies directed towards actual teacher practice in their schools, like creating their own materials, planning lessons, simulating classes, or watching videos with model classroom examples, were not common (12 to 37%) — this kind of methodology,when present, was offered only by programs organised by universities.

Regarding evaluation, 44% of the programs did not use any type of initial assessment. The ones that performed initial evaluation did it mainly on expectations towards the program and astronomical knowledge (37 and 31%). As for final evaluation, 87% of the programs inquired about course satisfaction, but only 37% evaluated astronomy contents, mainly to grade the participant teachers.

As for following up with the participant teachers in their subsequent practices, most programs provided means of contact (75%), but only some surveyed or interviewed the teachers about their classroom impact afterwards or visited their schools to support content implementation

(19 to 37%). Solely two programs sealed some institutional agreement with schools to aid the teachers in implementing what they have learned in the program.

Finally, the main reported challenges faced by the programs' organisers were the lack of support in the teachers' schools for their participation (50%). The difficulty in getting financial support to start or maintain the program was also common (40%), as well as the participant teachers' lack of previous astronomy knowledge (44%) and adapting classes to different knowledge levels (37%).

Conclusions and recommendations: In this study, we found a considerable number of astronomy teacher training programs offered in Chile in the last five years, indicating an organising and financing disposition from the local institutions. On the plus side, almost every program reported aligning their contents with curricular topics, considering misconceptions, including pedagogical content, and using hands-on materials. However, they were not so focused on teachers' actual practice, like offering opportunities for teachers to plan their own lessons or simulating their future classes.

Another important conclusion regards programs' duration: many of them lasted only a few hours, and almost all concentrated their classes in a short and intensive period. Furthermore, most programs, even the shorter ones, included several astronomical topics per edition, and almost half of our sample mixed primary and secondary education teachers in the same classes. Finally, most programs had few evaluation instances and hardly any follow-up with the participant teachers in their subsequent professional practice.

Given these conclusions, we recommend that future professional development programs in astronomy focus more on teachers' needs, for example, including less content, separating teachers from different levels, and directing classes toward their practice. They should also be of more extensive duration, include several evaluation instances, and follow up with the participant teachers by generating partnerships with schools. We hope that the evidence presented here can contribute to developing more effective programs that can significantly impact teachers' practice with their students.

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Knowledge of Primary Teachers About Key Concepts: the Fragile Foundation of Astronomy Education

Speaker: Ilídio André Costa, Santa Bárbara School Cluster, Porto Planetarium – Ciência Viva Center, Institute of Astrophysics and Space Science – Porto University, Portugal

CoAstro: @n Astronomy Condo is a citizen science project that engages primary school teachers in astronomy research during one school year. One of CoAstro's goals is to promote the appropriation of key astronomy concepts. To assess that, we apply the "Astronomy Questionnaire" (AQ), at the beginning and the end of CoAstro's first edition. The pretest results show low levels of teachers' knowledge (M=20.6%; SD=9.5%). From qualitative analyses, we link those results with gaps on initial training and with the lack of astronomy relevance in the national curriculum. This factor leads to teachers' low investment in astronomy continuous training. However, the post-test results prove that CoAstro's strategies can overcome this scenario and shows how everyone can learn about key astronomy concepts.

Talk link: https://youtu.be/BLaC2NcPCdQ

CoAstro – a citizen science project: The term citizen science is used to refer the public engagement in different stages of scientific processes [1, 2]. This collaborative concept, between astronomers and volunteers, is becoming an increasingly popular space in non-formal science education [3]. Indeed, citizen science can easily create a win-win context: it attracts more researchers to science communication and, on the other hand, allows the public to participate directly in scientific processes [4].

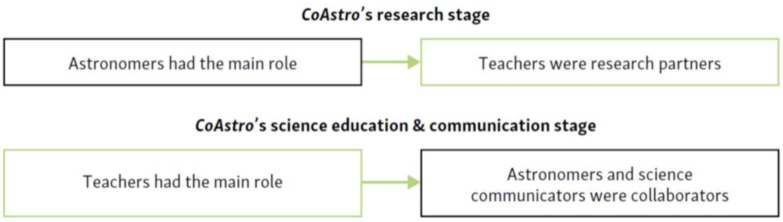

Figure 1: CoAstro's stages [7]

Thus, CoAstro: @n Astronomy Condo, defines itself as a citizen science project which, during one school year (2018/2019), had the participation of four astronomers, from the Instituto de Astrofísica e Ciências do Espaço (Portugal), nine primary school teachers, four disseminators and one mediator (these belonging to the Porto Planetarium – Ciência Viva Center – PP-CCV). Under this project, scientific content and processes were appropriated and integrated by teachers into school initiatives, enhanced by the "school effect" and "teacher effect" [5, 6]. This allowed the project to be extended to the school community with the engagement of approximately 1000 persons.

CoAstro acts in two main stages: the engagement of primary school teachers, with IA's research group Origin and Evolution of Stars and Planets and the joint promotion, by teachers, astronomers, and science communicators, of astronomy communication/astronomy education initiatives (Fig. 1).

The CoAstro's Astronomy Questionnaire (AQ): We based our AQ in the "Astronomy Diagnostic Test" (ADT). It is a multiple-choice test that evolved from a tool for measuring alternative conceptions in astronomy [8]. So, we started by translating ADT into Portuguese. This first translation was analysed by an astronomy expert. Subsequently, ADT was revised. This whole process of translation, analysis, and revision led to a first version of the AQ. An expert in Science Teaching and Dissemination then analysed this first version of the AQ. There was, at this point, a first stabilised version of the questionnaire that allowed us to proceed to the next phase: the pilot study, for instrument validation. Following this pilot study and with the changes that were made to the AQ the entire questionnaire was again analysed by the experts. Thus, we produced the final version of ADT in Portuguese, which we now call the "Astronomy Questionnaire".

The average age of AQ respondents was 45 years old. Eight respondents were female and one male. Four teachers completed high school in urban areas, two in suburban areas and three in rural areas. At the pretest, all teachers stated that they had never taken any specific astronomy course or participated in any astronomy initiative. The AQ pre-test was applied in the first CoAstro work package (December 2018). The post-test was applied in the CoAstro's last work package (July 2019).

Results: The results indicate that there was an increase in astronomy knowledge, from the pretest to the post-test. In the latter, the dispersion of the results was greater (SD=16.4%) with a higher test average (36%). Only one teacher kept the same number of correct answers. For the remaining teachers this number increased in the post-test. The average percentage of improvement was 15.9%. Despite this overall improvement, confidence in responses only increased by 0.3 points (on a scale of zero to five). The AQ data are compiled in Table 1.

Table 1: AQ pretest and posttest overall results.

	Pretest	Post-test	Δ post-pre*
Test average	20.6%	36.0%	10%
Standard Deviation (SD)	9.5%	16.4%	6.9%
Standard Error (SE)	3.17%	5.45%	2.28%
Maximum	42.9%	61.9%	19.0%
Minimum	9.5%	19.0%	9.5%
Average number of correct answers per teacher	4	8	4
Average number of wrong answers per teacher	17	13	-4
Average confidence in the answers (from zero to five)	2	2.3	0.3

* "Δ post-pre" corresponds to the variation between the post-test and the pre-test.

Conclusions: The AQ results demonstrate from pretest to post-test:

- a global increase in teachers' substantive knowledge of key astronomy content;
- an improvement in all conceptual categories of the questionnaire ("notion of scale", "movements", "gravity" and "general category");
- more significant improvements in thematic categories (and within these in items) that have been worked on the CoAstro more extensively and over a longer time;
- less significant improvements in items that appealed to some (albeit rudimentary) mathematical reasoning;
- despite teachers, in post-test, indicate not having much greater certainty in their answers, they nevertheless state having an opinion about more of the items under consideration;
- the wrong answers, in post-test, have a different nature, from the initials, revealing a process of evolution to the scientific concept (they come closer to it).

On the other hand, when comparing to the results of ADT, applied in the USA and Turkey, we find that, although the different contexts in these countries when compared to the portuguese context (in terms of initial teacher training), CoAstro teachers in post-test score, as expected, below Demming's respondents [9] – USA undergraduated students enrolled in introductory astronomy courses (CoAstro teachers 36.0% and Demming's respondents 4.3%). However, in post-test and after performing activities that allowed them to be come closer to the profile of those respondents (at pre-test), CoAstro's teachers outperformed Demming's respondents (32.4%). It should also be noted that CoAstro's teachers outperformed their fellow Turkish [10] (34.2%) and North American [11] (35%) teachers. Also noteworthy, and using only data from Brunsell and Marcks [11] (the other authors did not report this analysis), CoAstro's teachers were, in pretest worse than their American counterparts, in 18 items. This value is, in post-test, 11.

These results reveal that a citizen science project, built on a model such as CoAstro's, supported by a collaborative view of citizen science and based on a PEST paradigm, can effectively contribute to the increase of substantial knowledge of key astronomy content. For this purpose, the key elements appear to be the involvement of teachers in astronomy research that can motivate participants to undertake autonomous and, therefore, more meaningful and lasting learning.

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Why Astronomy Education Research is Important and How its Results Help in a Formal Astronomy Education Setting

Speaker: Saeed Jafari, University of Kurdistan, Department of Linguistics and Space Generation Advisory Council, Iran

Astronomy Education Research as part of Science Education has been critical not only in analysing the current state of scientific literacy and practice in schools, but also in strengthening teaching methods and teacher education. Here I briefly review how AER data in schools can help teachers estimate the media and cultural literacy in astronomy that students in different environments adopt, and in what way AER can guide redesigning learning environments based on critical thinking and problem-solving skills. Along the way we will see how insights from educational psychology, linguistics, neurosciences, cognitive science, and design studies allow schools to understand students better; and its results tell us how to redesign classrooms and learning spaces based on cognitive and social processes.

Talk link: https://youtu.be/Z1bSsNp3nzQ

Importance of AER: Theory and research are like pillars on which teachers' experiences, teaching and learning methods and approaches as well as pedagogy are placed. There is a huge variety of methods, approaches and challenges in astronomy education worldwide, owing to differences in school curriculums, standards, availability of resources, and general teaching practice. At the moment, more than 7000 languages exist in the world and the variety of nations cultures and heritage is so broad that every science educator in any district presents different and novel experiences and challenges to teach astronomy with regards to their culture and heritage. Therefore, doing research on astronomy education shows teachers, schools and scientific institutions how data can guide them through a range of backgrounds. For example, answers to questions such as which class of students are interested in which topics more or which educational approaches are more effective. Today's schools whether in less developed areas or developed cities need to provide an interaction between astronomy or science researchers and their educational structure. These interactions, experiences and lessons learned, which are done in the world's different formal settings and contexts, provide us with constructive and notable statistics. One of the most important aspects of AER is to share ideas and build a bridge between theoretical research and practical knowledge.

Significance of AER for educators in classrooms and schools: If we investigate most of the schools around the world, we can notice that a lot of schools don't have any researchers in researching fields of science education. As a result, many teachers are not familiar with teaching concepts, principles and skills of astronomy research or they don't know how to conduct them in their classes in order to assess students. Astronomy education research or generally science has a variety of aspects through which science educators can reach beneficial and efficient results based on their goals, approaches, needs and the class situation; in other words, their school environment. The students of many schools, whether those in the cities or rural areas, have different languages, cultures, races, nationalities, and also different situations. So this research can make it possible for schools to check and interpret their students' performance in any areas in order to let their teachers assess the level of the class.

Effectiveness and implementation of AER Data in classrooms: The most essential factor that can help us to know the students and understand them better is to collect their data and examine the data of every class or generally the school environment. Every teacher can have a deep look at his or her classes based on the data, statistics s/he gathers through tools such as interview, case study, survey, student work and so on. Such experiments can be either quantitative or qualitative. Collecting data of every student, every class and a school; in overall, allows the education society and teachers community to perceive how much linguistic and cultural diversity affects learning issues or how much the students of different social stratification and social class demonstrate interest and motivation for learning scientific topics. Ideas and results of the research which are done by AER society in different formal settings can also present thought-provoking numbers and statistics for formal teachers' community as well as education government body. Consequently, the output of such research and assessments regarding the context, situation, language and culture of every district, country and continent is so diverse and remarkable that this valuable data and evaluation process can inspire more effective standards of teaching and learning for both teachers and students societies.

Influencing of AER aspects on curriculum and development of students: A remarkable number of science educators in the world consist of physics and astronomy educators. Experiences and lessons learned of teachers are one of the most valuable data of research. It can be said that research on astronomy education has the key role in criticising and investigating education components such as curriculum, methodology, teaching and learning approaches, resources and training tools depending on the socioeconomics context and situation in every country. Taking a look at the curriculum and pedagogy of each country, we can find out that the culture and heritage of every country as the part which carries teaching and learning have visible effects on content, resources and standards of school books. So in one hand, teachers' community can develop the process of their curriculum in an effective way in their classes and school with the use of AER knowledge and attitudes as well as design the context, practical resources and localisation based on their social and geographical situations. On the other hand, observing the outputs which AER shows from the effectiveness of students learning in formal education settings, it's a vital need to use and interpret pedagogy knowledge for a better transferring of science-based subjects and concepts that every teacher should use in different social, political and cultural contexts. The numbers and statistics of AER make us think about how basic the role of scientific and critical thought and problem-solving skills is for the future generations.

Interdisciplinary fields matter: Strategies informed by cognitive psychology can help you remember names, concepts, and much more, and they have powerful roles to play in the classroom. Teachers can use these four strategies (retrieval practice, feedback-driven metacognition, spaced practice, and interleaving) with confidence because they are strongly backed by research both in laboratories and classrooms (Agarwal and Roediger, 2018). Also in psycholinguistics, this area looks deeply into linguistic abilities, disorders, performance, competence and diversity of each student. This knowledge will help teacher to reduce the intrinsic and extrinsic difficulties. Moreover, to helping future teachers understand how students learn best, neuroscience can help them manage student behaviour. Often, the reasons students behave poorly is due to stress (Matthew Lynch, 2017). This discipline shows how stress affects the brain, and how findings can help teachers better understand students' behaviour.

Impacts of cognitive and social processes of learners in formal education: Becoming a professional, experienced and knowledgeable teacher is really difficult and hardworking. We can't expect that teachers like doctors can investigate the students' behaviour and actions exactly or like sociologists are able to analyse and assess the social class and differences in participation and contrast among individuals and classes. However, it is possible to perform such attitudes and approaches in the class and at school through learning and using knowledge and techniques. At the same time, what helps AER through teachers is the cognitive and social processes which have a great importance in formal education. These two processes make a way in the teacher's mind, firstly how their social role will be in the future society and how they can explain a meaningful and respectful life, specifically a peaceful view of the world to the students from different social classes. Moreover, since physics and astronomy subjects are abstract, processes such as thinking, remembering, problem-solving, speaking and imagining will be more straightforward and more understandable for students from different academic levels or with different learning abilities. Consequently, different methods and techniques based on students' understanding can act as a bridge that makes it possible for the learners to gather facts, think about them and combine the new information with what has previously learned in order to grow their knowledge base.

Students' International Network for Astronomy

Presenter: Mahdi Rokni, Students' International Network for Astronomy, Iran

Students' International Network for Astronomy (SINA) is a social group of students in south of Iran since 2014 that has organised many astronomical activities and projects in the area. SINA has been organising international events of astronomy in relation to cultures, history and societies, in cooperation with Iranian Teachers Astronomy Union, Astronomy Day in School (ADiS) and the Network for Astronomy School Education including the main Persian astronomical ceremonies for ADiS connecting more than a thousand students from over 15 countries around the world. It is important to highlight that SINA has been establishing some methods and ideas for underage children and elementary students.

Poster link: https://astro4edu.org/siw/p99

Students' International Network for Astronomy was established by students in a small city in the south of Iran. It was their desire to globalise all the activities and plans that they had been carrying out at the Mehr observatory. Some of these activities contain a lot of social skills and different learning methods for students.

The main aims of this network are 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 the global environmental concerns and world peace, letting students make friends without any limitations and introducing their own culture, activities and feelings to each other, using astronomy and other activities to help them learn social skills such as team-working, event planning and management, cooperation and formal behaviour, and other goals that can be related to the international strategy plans.

One of the most important activities that has been ongoing since 2013 in Iran is the "Sky Explorers festival". It is an outdoor camping event for students in order to stay outside for a day, especially at night, with their friends and combine it with astronomy lessons and observations. Some of the goals that we achieved in this festival are observing the Sun with a solar telescope, camping and setting up tents as a group, building instruments, observing the night sky, recycling and reusing material brought by students, educational packages, team-work, and communication.

The future goals of SINA are to establish the formal constitution and curriculum for SINA with a working-group, introducing the network globally by planning new events and projects, accepting new students as official members and supporting their projects, preparing a platform for registration and accessible information, cooperation with other associations and international projects, and special projects and methods for elementary students and underage children.

Justifications for Teaching Cosmology in Basic Education: Analysis of Papers and Curriculum Documents

Presenter: Camila de Macedo Deodato Barbosa, University of São Paulo, Brazil

Cosmology as a research area feeds human curiosity to seek answers about the birth of the universe. From this perspective, how can the teaching of Cosmology mobilise scientific practices in the classroom? This work aims to build justifications for the teaching of Cosmology from a literature review and analysis of Brazilian state curricula. The analysis points out that teaching Cosmology in Basic Education can mobilise discussions about the nature of science, promote the theme of modern physics, establish relationships between technology and scientific development and build notions of location on a cosmic scale.

Poster link: https://astro4edu.org/siw/p100

Origin and evolution of the universe has always been presented in the history of mankind and remain an important part of knowledge construction in modern science. The main objective of this research is to identify the main justifications presented by researchers in science teaching for the insertion of Cosmology in basic education, since this topic is of great interest to students [Aguiar (2010), Skolimoski (2014), Bagdonas (2011)]. To compose our corpus of analysis, we selected the research published in journals: Revista Latino-Americana de Educação em Astronomia (RELEA), Caderno Brasileiro de Ensino de Física and Revista Brasileira de Ensino de Física, as we traditionally have more works published on teaching topics of astronomy. Master's and PhD theses on teaching cosmology were also analysed.

The main justifications found were: location on the cosmic scale; aspects of the nature of Science; technological perspective of Science; Modern and contemporary physics.

Regarding the understanding and location of the Earth on a cosmic scale, Leite (2006), Aguiar and Hosoume (2018) and Eriksson (2011) indicate that the construction of a cosmological vision leads to a broader and more complex understanding of the universe we are part of.

Authors such as Arthury (2010), Bagdonas, Zanetic and Gurgel (2017) and Porto and Porto (2008) find in Cosmology an opportunity to work with the nature of Science, through the History of

Science. For these authors, this approach allows building critical perspectives for scientific paths, in order to break paradigms about Science.

Fróes (2014), Skolimoski (2014) and Bagdonas (2011) also indicate that Cosmology can be a way to problematise and relate science to technology, establishing both the limits and the advances of each era. In Cosmology in particular, telescopes have allowed us to look further afield and this opens up possibilities for us to better understand the evolution of the universe.

Porto and Porto (2008), Aguiar and Hosoume, (2018), Sales (2014), Skolimoski (2014) and Nascimento (2017) defend the interdisciplinary potential of Cosmology. Thus, for these authors, this theme allows approaches that involve from Modern to Contemporary Physics, as well as other areas such as astrobiology and -chemistry.

Several authors point to the importance of working with Cosmology in Basic Education, evoking justifications that were common among them. This bibliographic survey brings us elements to make curricular choices, since they can indicate some formative potential of the proposals that involve studies of the universe.

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A Typical Case on Teaching Hertzsprung–Russell Diagram by Exploring the Nature of Astronomy Diagrams

Presenter: Zhang Yiming, Astronomy Department, School of Physics and Electronic Science, Guizhou Normal University, Guiyang, China

The H-R diagram, a typical case for teaching improvement on scientific methods in astronomy, is used to reveal the process of the stellar evolution. The diagram was created and improved by induction, while the related explanation of stellar evolution by deduction. Therefore, the relationship between such inductive diagram and the deductive explanation can cause methodology confusion. It is possible to clarify the confusion by exploring the diagram among the modern astronomy history, analysing the theory of stellar internal structure developed in the same era and visualising the generation of the diagram. It is expected to further understand the nature of the diagram by such efforts.

Poster link: https://astro4edu.org/siw/p101

The special characteristics and significance of astronomy calls for higher quality of the undergraduate teaching on astronomy. Among the courses, fundamental astronomy plays a very important role although its teaching is rarely studied by educators in China. As the core of astronomy teaching, the Hertzsprung–Russell diagram (H-R diagram) can be studied as a case for improving the teaching considering its special role in history and several scientific methods in it.

The H-R diagram is used to reveal the process of stellar evolution. For our undergraduates, such judgement seems to be taken for granted. The fact is that no one is able to explain it exactly. Dating back to the formation of the diagram, scientists and assistants obtained stars marking as the remarkable scatter-plot and explored certain relationships by induction. However, the explanation for stellar evolution is studied by deduction. Therefore, the relationship between such inductive diagram and the deductive explanation can create some confusion among students and teachers when they try to understand the H-R diagram. It is possible to clarify the relationship in three ways:

First of all, it is important to explore the basic need for creating the H-R diagram as part of modern astronomy history: this diagram catered to the need for classifying various types of stars that were observed and analysed with different scientific methods used for their classification. Related contributions by Astronomer Rockier, Ms. Cannon and Ms. Murray should be rediscovered.

Secondly, it is necessary to analyse the theory of the stellar internal structure developed in the same era as the H–R diagram. For example, Internal Constitution of the Stars by Arthur Stanley Eddington and Vogt-Russell theorem are representative of explaining the distribution and evolution of stars as well as the synthesis and evolution of elements on the H–R diagram.

At last, with the improvement of observational methods and computing performance, astronomers are able to show the generation of H–R diagrams by rotating the three-dimensional distribution of various types of stars in one globular cluster, which will help students understand the H-R diagram more visually and professionally.

A deeper understanding of the scientific methods and theories can increase students' appreciation for the H–R diagram. Implementing these ideas in classroom can be challenging, but teachers should try to relate the history and methodology of the H–R diagram with help from experts and carry out group discussions to achieve the core objective for teaching.

Astronomy Worldviews: How Undergraduate Students in Introductory Astronomy Courses Relate Science to Society, Quality of Life, Daily Life, Government, & Religion

Presenter: Hannah Lewis, Department of Astronomy, Wesleyan University, Middletown, CT, USA

Collaborators: Sanlyn Buxner, Chris Impey and Edward Prather (University of Arizona, Tucson, AZ, USA) and Benjamin Mendelsohn (West Valley College, Saratoga, CA, USA)

Understanding how students relate course material to beliefs about social frameworks outside the classroom can help instructors make courses more inclusive and engaging. We report on a study of undergraduate students enrolled in introductory astronomy courses, who completed a five question survey about the relationship of science to society, quality of life, daily life, government, and religion. We find that a majority of students believe the relationship of science to society is more significant than insignificant; the influence of science on quality of life is more favourable than unfavourable; everyday life is more connected than disconnected to science; the government is more supportive than unsupportive of science; and religion and science are more not in conflict than in conflict.

Poster link: `https://astro4edu.org/siw/p80`

When a student enters a classroom, their beliefs about the greater world are not left at the door. As such, it is important to understand how students relate the material they learn in science courses to their beliefs about social frameworks outside of the classroom. Previous work has investigated student's basic science knowledge, related attitudes and beliefs (e.g. Impey et al., 2017), as well as quantitative reasoning (e.g. Follette et al., 2015, 2017). The current study focuses on frameworks not addressed in these previous works.

Research Questions:

1. How do students characterise the relationship between science and society, quality of life, daily life, government, and religion?

2. How consistent are student responses across the five domains?

3. To what extent do the examples included in student responses intersect across the five domains?

Methods: We report on a study of undergraduate students enrolled in introductory astronomy courses at the University of Arizona (N = 283), who completed a five-question survey about how

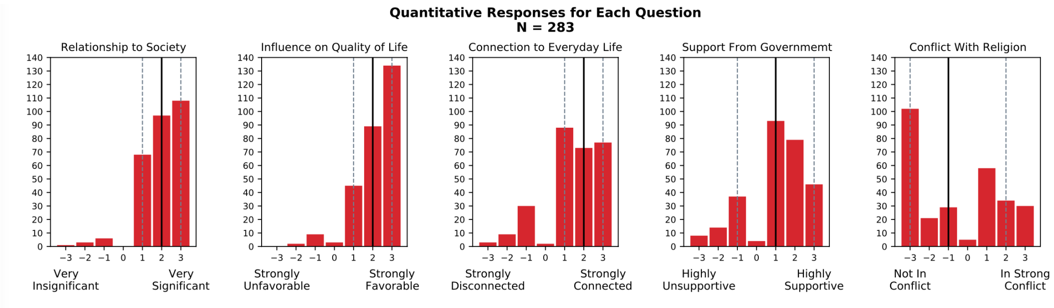

Figure 1: The distribution of quantitative responses on a -3 to +3 scale for each question. Responses on the Society, Quality of Life, Daily Life, and Government strongly skewed positive, while the Religion question has a bimodal distribution, indicating more polarised beliefs.

they perceive the relationship of science and society, quality of life, daily life, government, and religion. The instrument measures both quantitative and qualitative aspects of these beliefs, and as such allows us to characterise the relative strength and intersections of responses to each question.

Preliminary Results: We find that a majority of students believe the relationship of science to society is more significant than insignificant (96%); the influence of science on the quality of life is more favourable than unfavourable (95%); everyday life is more connected than disconnected to science (84%); the government is more supportive than unsupportive of science (77%); and religion and science are more not in conflict than in conflict (54%). We also find significant correlations between student responses about the connections between these five topics.

Application to Classrooms: These preliminary results characterise pre-existing beliefs on five separate topics for non-science major students in introductory science courses, which are opportunities to evaluate the connection between science and societal frameworks. This can be used by course instructors to better understand how students are relating course material to these external topics.

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Promoting Basic Sciences Campaign Reveals the Actual Contribution Astronomy and Spatial Sciences Currently Have to STEAM Education in Romania

Presenter: Elisabeta Ana Naghi, ESERO, Romanian National Committee for Astronomy, Dana Ficut-Vicas, Astronomical Observatory Cluj-Napoca of the Romanian Academy and Cautnic Daniel, Samuel von Brukenthal National College, Romania

With the IYBSSD2022, the Romanian National Committee for Astronomy (CNRA) has launched a campaign to promote basic sciences in over 100 schools in Romania from both rural and urban areas. Within this campaign we investigate the role that basic sciences (astronomy and space science plays in school education and the impact of the activities within the campaign in motivating students towards studying STEAM and choosing STEAM careers. Here we present results of the analysis of the initial survey. This analysis shows the contribution astronomy and space science currently have in STEAM education in schools in Romania and is an essential starting point in building future programs and campaigns that can focus on the urgent needs of the STEAM education in our country.

Poster link: https://astro4edu.org/siw/p120

During the International Year of Basic Sciences for Sustainable Development (IYBSSD2022), the Romanian National Committee for Astronomy (CNRA) has launched a campaign to promote basic sciences in 167 schools all over Romania. We took this opportunity to run a research study on the role of basic sciences and in particular, astronomy plays in motivating students towards STEM and choosing STEM careers. Two surveys were administered one before and one after the activities of the campaign took place. In this study we present the results of the initial survey, administered to 1548 students, mostly from urban areas (80%), 59% girls and 41% boys. The only bias in our sample is the fact that the schools have voluntarily applied to participate in the campaign. With this initial survey we wanted to assess the current contribution of astronomy and space science in STEM education in Romania.

According to our research presently Romanian students have a high interest in STEM activities, which however is only cultivated in school in a predominantly traditional manner. Hence Romania has a great potential in basic sciences, which remains predominantly not valorised because interdisciplinary connections, transferable skills and solving real life problems are not sufficiently practised by students for them to get confident in the benefits of the knowledge they learn in school. Because astronomy is not part of the national curriculum and the number of schools offering optional astronomy courses is quite low, students hardly get in contact with this science. Hence, astronomy is not part of the learning reality of Romanian students. Although astronomy is one of the oldest sciences in Romania, currently astronomy is under developed in our country, hence not a factor of influence in STEM motivation in Romania nor a source of role models that attract students into science. Astronomy and space sciences are not very present at the extra-curricular level either, as most interviewed students admit not reading about science and astronomy outside school hours and rarely taking extra-curricular activities, such as going to a planetarium, an astronomical observatory, a museum or to science fairs.

Astronomy and space sciences through their highly interdisciplinary character are widely known to have an impact in high quality education and in attracting students towards STEM. Astronomy and space sciences can help students develop critical thinking, convey meta-cognitive skills such as objective argumentation, logic formulation and science communication, allow connections between different sciences such as math, physics, chemistry, biology, computer science, and many more. Yet, all this impact on education is lost in countries where astronomy and space sciences are devolving instead of strengthening their presence. Consequently, in countries such as Romania where astronomy is not part of the national curriculum students not only do not benefit from the impact on high quality education astronomy has but are limited in their perspective of basic sciences as their view is incomplete. This has an important effect not only in the education of our students but also on astronomy research and development in our country. The continuity of this science in our country is at threat due to lack of future generations of astronomers. As it has been seen in other countries, astronomy can act at the extra-curricular level instead, but in countries where astronomy is less developed it is very challenging to do so outside school because isolated activities are not enough but rather long term outreach programs are necessary.

Student Interest in Astronomy and Other Subjects: Research and Practical Experience

Session organisers: Emmanuel Rollinde (OAE Node France), Assia Nechache (OAE Node France), Tshiamiso Makwela (OAE Heidelberg), Estelle Blanquet (University of Bordeaux, France), and Merryn Cole (University of Nevada, Las Vegas)

Session overview

Astronomy education research has been considered a discipline-based education research since 2011 (date of Bailey's review). As such, it provides an insight into concepts and into students' interest in and understanding of those concepts.

This session focused first on students' mental models in astronomy. General methodology to characterise those models will be discussed as well as their evolution through specific pedagogical designs. A particular focus is made on cognitive thinking and mental models about spatial thinking, relativity principle, and referential frame.

Astronomy is considered a more global "gateway" to science, focusing on interdisciplinarity and methodology of investigation. The gender issue in science is also discussed in the specific context of astronomy.

Interestingly enough, the studies presented in this session include different scales, from a case study with one class to an international comparison, with qualitative and quantitative analysis.

Thinking about the Stars - Mental Models in Astronomy

Speaker: Malte Ubben, WWU Münster, Germany

Knowing students' mental models is an important step in teaching science. There are many pre-conceptions that students bring to the classroom and that determine their way of thinking about the world. In this contribution, several prominent mental models in astronomy held by students are presented, as well as how researchers go about obtaining them. Additionally, a common process of mental model development is discussed using the example of black holes.

Talk link: `https://youtu.be/cw9Jco1CvVg`

When trying to describe learning processes, the mental model is a very useful tool. Mental models are the concepts learners bring to the classroom. They are created via the interplay of previous and new experiences and are thus individual to each learner (Piaget, 1951). Mental models consist of two different components: a gestalt and a functionality (Ubben et al., 2022). For example, the mental model of a cake has a certain gestalt – there is an image associated with it, a taste, a smell. One could also see this gestalt as the "surface level" part of the mental model. In the second component, the functionality, it is important what the mental model signifies. By thinking of the cake, one could see it as an expression of hunger or of satiation. Mental models are a central part of didactics of physics, as lessons must be prepared with them in mind to ensure learning material that is fitted to the class. Therefore, a lot of research has been done both to catalogue common types of mental models and to model how they emerge and develop.

In astronomy, mental models are therefore important for teaching as well and several key ideas that make up inadequate mental models have been found by researchers. The most prominent type of misconception is the notion that mental models are direct replicas of reality (Treagust, 2002; Ubben et al., 2022). In astronomy, as in other subfields of physics, these often manifest in novice learning. One prominent example is that students – especially of younger ages – often think that stars are really small and have jags (Favia et al., 2014). Another similar misconception is that learners think the planets move on strings around the sun, which was even held be Kepler (Kuhn, 2016). Additionally, it is often believed that planets are roughly the same size as each other and the sun and are very close together (Favia et al., 2014). This misconception is often ascribed to originate from pictures in textbooks or other media. The research on mental models in astronomy is mainly limited to the solar system and in particular the relations between Earth,

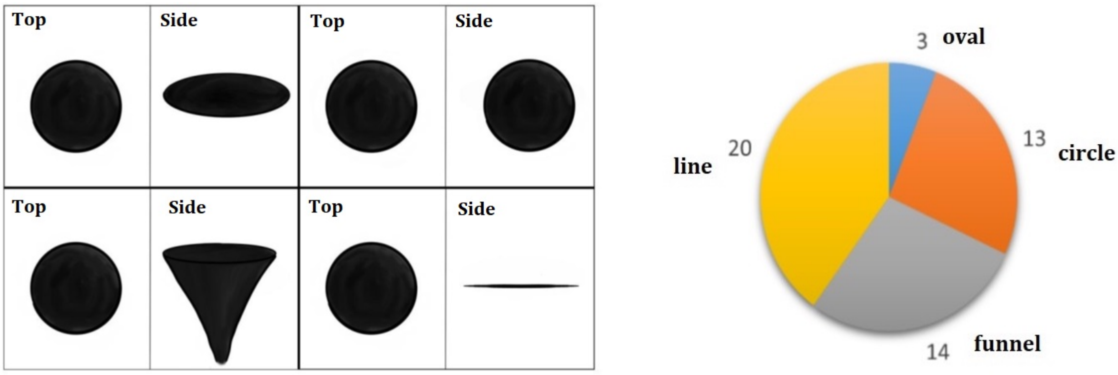

Figure 1: The four types of black hole shapes the participants drew.

Sun and Moon (tides, eclipse etc.). Research in more modern concepts is rather lacking, but this poses new opportunities for research. One of the topics rarely subject of mental model research is that of black holes. Therefore, we conducted a qualitative study to assess what learners associate with the term “black hole” in astronomical contexts, and especially what gestalts they associate with the term (Ubben et al., 2022). In the study, we asked 26 astronomy novices to draw a black hole from the top and from the side and to describe what they understood by the term. The task was posed this way to make the participants think beyond a circular shape. All in all, four types of drawings were extracted from the material (see Fig. 1): The participants’ imagines a black hole as looking like a sphere, an ellipsoid, a funnel (or cylinder) or a disc.

Fourteen of the participants drew a black hole as a sphere or ellipsoid, 8 drew a funnel-like structure and 4 drew a disc. The different types of drawings from Fig. 1 were then given to 50 non-astronomy students at university. The distribution of choices of side-view can be seen in Fig. 1.

It is remarkable that the number of participants choosing the line (and thus a disc shape overall) is in relation to the others a lot higher than in the drawing task, whereas the oval shape (and thus an ellipsoid shape overall) was almost not chosen anymore. We presume that this is because in the drawing task, the side-view of a disc was hard to conceptualise and thus was rarely drawn. For our number of participants, we found in summary a similar amount of disc, funnel, or spherical shapes for the mental models of the black holes. Further surveys should be conducted to get a more generalised relation.

When looking at the descriptions of the black holes made by the participants, there are four general categories that match with previously shown categories of mental model development (Ubben & Bitzenbauer, 2022): Several of the students did not know what a black hole was and were thus in a very early stage of mental model development. Several others only had images in their mind when asked about black holes, showing first aspects of mental model development – the formation of a gestalt. Most people described the gestalt and the properties of black holes, such as attracting masses, showing a more elaborate development of their mental models. This type of mental model is the same as the idea of mental models being direct replicas of reality. Finally, few students showed a very deep understanding of black holes by only limiting themselves to the physics behind them and their functionalities. We therefore assume that the development of mental models of black holes is similar than that of atoms and photons (Ubben & Bitzenbauer, 2022).

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Preschool-Age Children's Use of Spatial Thinking When Making Sense of Astronomical Phenomena

Speaker: Hannah Lewis, Wesleyan University, Middletown, CT, USA

Collaborator: Julia Plummer, The Pennsylvania State University, University Park, PA, USA.

Engaging children in spatial thinking predicts future success and participation in science. This study investigates how early childhood astronomy programs engage preschool-age children in spatial thinking. We use a qualitative framework to analyse observable behaviours, called spatial sensemaking practices, and infer the children's cognitive processes, called spatial skills. Results suggest children most often engage with Extrinsic-Static spatial skills, which involves comparing the properties of static objects. Also, all of the identified spatial sensemaking practices helped facilitate multiple spatial skills, suggesting behaviours can engage children in various cognitive processes. Finally, each program facilitated spatial skills in only one to two of the 4 broad spatial skill categories.

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

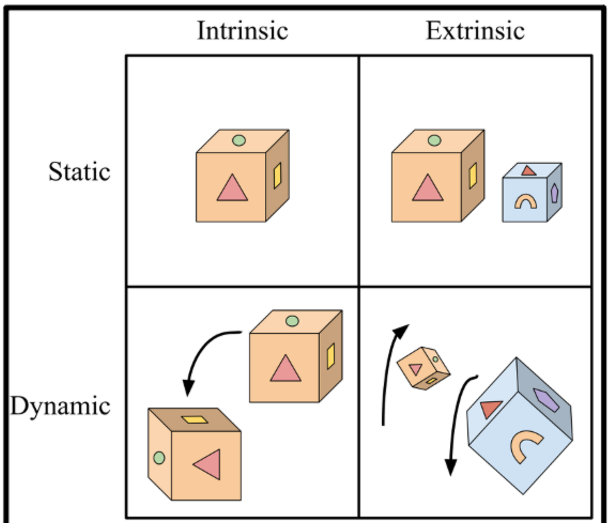

Figure 1: Classifications of cognitive process in the distributed spatial skill quadrants. Figure adapted from Uttal et al. (2013).

Early use of spatial thinking is critical for children to develop expertise in future science, technology, engineering, and mathematics (STEM) education [1,2,3]. Understanding how educational activities facilitate children's engagement in spatial thinking strategies can inform curriculum design and better prepare a greater number of students for future academic success. We used two frameworks to analyse how children engage in spatial thinking during informal astronomy programs.

Framework 1: Spatial Skills
Spatial skills are the cognitive processes used by children to engage with spatial concepts. We categorised the specific spatial skills (e.g., categorising space, describing relative size) as well as into broader categories (see Fig. 1) [4].

Framework 2: Spatial Sensemaking Practices
Spatial sensemaking practices are the behaviours children use to facilitate spatial skills [5]. These are directly observable behaviours, and we analysed how children used them to infer the children's spatial skills. Examples include gesture, spatial talk, and sketching.

Research Question: *To what extent do museum astronomy programs encourage preschool-age children to engage in spatial sensemaking practices and inferred spatial skills?*

Methods: We analysed video data of children in seven different museum astronomy programs at a small science center in a high socioeconomic status college town in the Northeastern United States. The programs were developed for children aged 3-5 years old and covered seven different astronomical topics: shadows (n = 6 children); phases of the Moon (n = 12 children); lunar craters (n = 10 children); Martian landscapes (n = 15 children); Earth's rotation (n = 6 children); stellar distances (n = 6 children); and constellations (n = 5 children).

Finding 1: Children Most Commonly Used Extrinsic-Static Spatial Skills
Of the four broad spatial skill categories (see Fig. 1), children most often engaged in Extrinsic-Static skills, meaning they were comparing the static properties of multiple objects.

Finding 2: All Identified Spatial Sensemaking Practices Facilitated Multiple Spatial Skills
This means that children use the same behaviours (the spatial sensemaking practices) to engage with multiple cognitive processes. For example, the children used object manipulation to engage in dynamic spatial relations during the Earth's Rotation program, and to engage in categorising space during the Craters program.

Finding 3: Three Programs Engaged Children in Two Spatial Reasoning Quadrants, and Four Programs Engaged Children in Only One Spatial Reasoning Quadrant
These museum programs only engaged children in one or two of the four broad spatial skill categories. Further analysis is needed to determine whether this is related to the astronomical topic, type of activity, or other factors.

Summary: While museum programs do facilitate children's spatial thinking, multiple programs around a range of astronomy phenomena are needed to engage children in all four spatial skill quadrants.

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How Astronomy Helps Primary Teachers and Secondary Students Understand the Relativity Principle

Speaker: Emmanuel Rollinde, CY Cergy Paris Université, LDAR, France

In an astronomical context, we explore the teaching of Galilean motion principles observed in different reference frames. A first short-term experiment (two sessions of 2 hours) was conducted with grade 10 students in a French high school using a Human Orrery to enact movements of planets and the Sun. Results from pre- and post-test proved a significant and positive evolution in the long term. A second one-year-long experiment has shown, through regular interviews, the resistance of pre-service primary teachers to accept the equivalence of geocentric and heliocentric frames. In both cases, the context of astronomy proved to be efficient in forcing the emergence of a new conceptual scheme.

Talk link: `https://youtu.be/a5CAfPgh0n0`

Ability to think about physical quantities related to movements in different reference frame is important for spatial thinking. It has been very often shown that few people are able to do so. Hence, terrestrial frame is solely used for movement observed on Earth, while heliocentric frame is used for movements in the Solar System. We explicit the strength of the faith in the heliocentric frame in a case study of two pre-service primary teachers. Then, we describe an embodied pedagogical design that has proved to be able to challenge the heliocentric description in the context of the movement of Earth, the Sun and Mars. This design, based on astronomy only, has a significant impact about spatial thinking in other contexts too.

I discuss here the specific question of changing perspective – moving from one reference frame to another – that is of interest for both physics and mathematics education (Joshua et al., 2015). The key point is the student's ability to think about physical quantities related to movements independent of their definition of a reference frame. Since the seminal work of Saltiel & Malgrange (1980), it is known that one has the tendency to describe movements from a "favourite" referential frame. Different main "favourite" referential frames are used. Rollinde et al. (2021) use three situations related to two "favourite" referential frames to discuss this difficulty. Firstly, our perception is so strongly connected to the ground that we consider all movement relative to it (or to the floor of the train in a moving train). First situation: if we observe two skydivers falling with a constant but different speed, one of them lost his sun-glasses and the second one catches them; very few will believe that the path of the glass as observed by the first skydiver has a distance of zero. Second situation: if we are sitting on a bench near a merry-round, you will never "believe" that your child on the merry-round may be at rest. Yet, they are at rest as they are observed by another child on the merry-round. Secondly, in astronomy, one naturally trusts the authority of science since there is no "natural" frame to refer to (e.g., Shen & Confrey, 2010; Blanquet & Picholle, 2018). Hence, the heliocentric frame is another "favourite" referential frame to think and discuss about movement of planets. Very few may say that the Sun is moving around Earth. Hence the third situation: Very few will say that Jupiter may have a non-circular movement if it is observed from Mars. Rollinde et al. (2021) have proposed those situations to 246 grade 10 students (about 15-16 years old). Less than a half gave the right answer (that distance travelled and speed are different for the two observers (see Rollinde et al., 2021 for details about the questions asked and the statistics of the answers).

The fact that distance and speed depend on the observer is called the relativity principle. Two questions are asked: May the argument of authority be challenged either by a long-term but standard lecture with a group of pre-service primary teachers or by an embodied designed teaching lesson (Cole et al., 2018; Abrahamson et al., 2020). Once the argument of authority has been challenged, is the relativity principle used in spatial thinking?

Together with a colleague in mathematics education, we proposed a 8 times 3h-sessions. Lecture in a pre-service primary teachers training institute. The objective of this lecture was to invite students to create an activity that combines science and mathematics. Two students choose astronomy and the path of the Sun as their subject. None had a solid scientific background. I took this opportunity to follow their cognitive evolution about the path of the Sun with the underlying question: “Does the Sun revolve around Earth, or Earth around the Sun?”. The relativity principle says that both is true, the first in the geocentric frame (during one year) or the terrestrial frame (during one day), the second is true in the heliocentric frame. Would that be the case for our pre-service primary teachers?

Since the beginning of their design, they set up the goal of the session to provide a meaning to the phenomenon of day and night. The knowledge to be acquired by their student was that Earth revolves around the Sun, “they have to know this” according to one of the two teachers, called L. The second teacher is called J. The first activity chosen by L and J was to have their class draw the Sun as seen in the sky over the school’s building, from 9 am to 5 pm. On coming back to the training institute, L worries immediately that observing the Sun moving around Earth may create confusion. Indeed, from L’s “favourite” referential frame, Sun does not move (in heliocentric model). So, L wonders how to explain children that Sun does not move. As I asked L “Do you realise the Sun revolves around Earth on your drawing?” L answers: “yes, but it is an illusion”. Then, L tried to use a globe to “prove that it is the Earth that is moving around itself”. During this discussion, J was more open to the relativity principle and seemed to accept that it depends on the observer. During another class activity, L used a globe and explained that she had to admit that day and night may be explained by the movement of Earth around itself or of the Sun around Earth. L then said: “I did not realise it depends on the observer”.

I conducted an interview at the end of the year with both L and J. L explained that “it is good to use heliocentric since the Sun does not move [L] was anxious to have the Sun moving, since they will believe that the Sun revolves around Earth”. Then J noticed that “Yes, but it moves in the sky and you see that on your drawing!”. One may conclude that J has accepted the relativity principle, while L could not challenge it even after regular discussions in class with J and I, and after activities of drawing and with a globe. Yet, at the end of the interview, J concluded with “We use the heliocentric model to explain that the Earth revolves around the Sun”. This case study on a long-term basis confirms previous conclusions by the research about the strength of the faith in the heliocentric model that does not allow one to think about astronomy in a different frame (even the natural terrestrial frame).

Rollinde et al. (2021) have used a heliocentric embodied model to challenge it. Students are asked to move and to enact different frames with their arms (see details in this publication). The important conclusion here is that observers and actors all ended with the conclusion that Sun does move in 24h and that Mars does not move on a circular orbit if it is observed from the geocentric frame. Students were really surprised and had difficulty to admit that Mars may be at rest when seen from Earth (so in their drawing) even if they see Mars moving in the heliocentric frame. This challenge led them to a correct answer in all three situations described above, so not only in the astronomy context. This change in their conception and use of spatial thinking was statistically significant and was confirmed twice in two consecutive years. The teaching sequence was conducted by the researchers the first year, and by the school teachers in the second year with similar results (not published yet).

We set up two designs, one based on a discussion-based long-term session with pre-service primary teachers and the other based on an embodied short-term session with grade 10 students. The first confirmed the strength of the faith in the heliocentric model. The second was a successful challenge to this model, and more importantly, the result was efficient in a context other than astronomy. Hence, it confirms that astronomy is an efficient and rich context to challenge misconceptions.

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Everybody Knows That the Sun Does Not Revolve Around Us! Paradigmatic Pressure, Relativity of Motion and Strong Emotions

Speaker: Estelle Blanquet, Laboratory LACES, University of Bordeaux, France

We have shown in previous studies that the difficulty of accepting the concept of relativity of motion whenever it contradicts the Copernican interpretation (“the Earth revolves around the Sun and not vice versa”) is widely shared both by students and by their teachers and even by some professional physicists. We have therefore developed fiction-based sequences to facilitate the overcoming of this obstacle by primary and secondary school students and by their teachers. We present here a qualitative (n=16) and a quantitative (n=120) study conducted with pre-service teachers, probing the strong emotions felt during the investigation process and highlighting their reluctance to accept the current relativistic paradigm in the context of Earth/Sun movements.

Talk link: https://youtu.be/a32Aj6Pk71c

French junior and senior high school students are all taught that the description of the motion of an object depends on the observer who describes it. But how do they react when they are asked this question in different contexts?

A first study [1] interrogated 5581 participants, including 3950 first-year science students at the beginning of the year, and both pre-service (980) and in-service (400) primary school teachers. We proposed three formulations addressing the same issue: The first one asked the participants to position themselves in relation to a sentence learned in class, namely *The description of the motion of an object depends on the observer who describes it*, by answering yes, no or “I don’t know”. The second formulation *A child is on a merry-go-round. Sitting on a bench, the mother sees him rotating at a constant speed. From the child’s point of view, it is not the merry-go-round but the mother who turns* was also a multiple choice question, yes, no or “I don’t know”. It is a classic situation used by many French teachers. The third formulation was an open-ended question: *A person observes the motions of the Sun in the sky and of the shadow of a stick on the ground during the day. They argue that the Sun turns around the Earth in 24 hours. What do you think?*.

The situations of the merry-go-round and of the Earth/Sun system are mathematically similar. If one does accept that, from the point of view of the child on the merry-go-round, it is the mother who is moving, then we might expect a similar answer to question three, namely that from the point of view of an Earthly observer, it is the Sun that is moving across the sky.

Nevertheless, the Earth/Sun question draws the participants’ attention to a key issue of the Copernican quarrel, according to which it is the Earth that rotates around itself and revolves around the Sun *and not the opposite*. We have classified their responses to this question into three categories. ‘Copernican’ responses include responses indicating that it is the Earth that

Table 1: Select excerpt of students' responses

Throughout the modelling, I was getting lost. Was my knowledge wrong? Why teach this to the students if it is not reality? I was trying to find out where we were going. I was especially confused. Finally and gradually, I understood the objective: to make us understand that everything depends on the reference frame we consider. If we take the Sun as the reference point, then the Earth would revolve around the Sun.
I felt disoriented because all my knowledge was questioned. It is quite disturbing because it requires deconstructing a model that we are taught from primary school and that is reassuring. We have the impression of control when we say to ourselves that "the Earth revolves around the Sun".
When I came out of this course, I was excited to tell everyone that the question "Does the Earth revolve around the Sun or is it the other way around" is really a question of the point of view. I was amazed at how reluctant the people were to question what they had always been told. After this disappointment, with some classmates, we talked about it again. A feeling of injustice, or rather of revolt against the teachers who had always told us that the Sun was not moving, without ever specifying the point of view, then appeared.
I found this session very interesting but also very disturbing. This session will remain very important for me, we have already talked about it several times with other students, so it is difficult, I think, for us to accept these two theories.

revolves and not the Sun. The category of 'relativistic' responses includes responses indicating that it depends on the chosen frame of reference. The third category ('Other') includes all other responses.

So how do the participants in the study position themselves in relation to these three questions? They overwhelmingly agree in abstracto with the formulation learnt in class (91%). A significant majority still agrees with the idea that from the child's point of view on the merry-go-round, it is the mother who moves (78%). But in the Earth/Sun situation, their answers change radically (5% of relativistic responses for first year science students). The Earth/Sun context seems then to sweep away the application of the principle of relativity in this specific situation and to yield the participants to revert to thinking in accordance with the Copernican paradigm. This is a signature of what we have called the Copernican *paradigmatic pressure* and which we have qualified as strong insofar as it can induce the negation of the principle of relativity in favour of a conformist thinking. Another interesting finding of this study was the very strong reactions of some participants to a person stating that the Sun revolves around the Earth (e.g. "*You should go back to school because this is not the Middle Ages anymore!*", "*No, you're stupid, it's the other way around*").

We have therefore developed sequences for working on the relativity of motion in an astronomical context by using fiction [2, 3]. The aim was both to remove epistemological obstacles [4] and to provoke a perspective likely to attenuate the virulent reactions of participants confronted with a challenge to the Copernican paradigm. These sequences have been carried out on multiple occasions but we focus here on the Rahan sequence [3]. Following this work, we asked 19 future primary school teachers who had previously received a training in this exercise to describe their feelings and the memories induced by the sequence (see table 1).

Overcoming the Copernican paradigmatic pressure appears to be a long but feasible journey. Nevertheless, this requires educators to be aware of and to underestimate neither the weight of the paradigmatic pressure, nor the emotions involved. As educators, they should be careful to systematically specify their choice of frame of reference in their interventions.

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The Practice of Astronomy Mini Exploratory Research in Shenzhen No. 2 Experimental School

Speaker: Zhenhuan Hu, Shenzhen No. 2 Exp. School, Nanjing, China

Supported by the Shenzhen Education Bureau, Shenzhen No. 2 Experimental School has carried out a series of Students' Astronomy Mini Exploratory Research, such as "How high is the lunar crater?", "solar prominence and solar cycle" etc. Mini exploratory research refers to the interdisciplinary research-based learning project carried out by students in the subject field or the real life situation. Students try to solve problems through investigation, experiment, observation, analysis, discussion, and practice. Unlike professional research, it does not focus on putting forward new theories, but guides and encourages students to conduct in-depth learning in the way of scientific research, stimulate their exploration interest, enhance their team cooperation ability, and develop an innovation consciousness.

Talk link: `https://youtu.be/nR5maBiXe-s`

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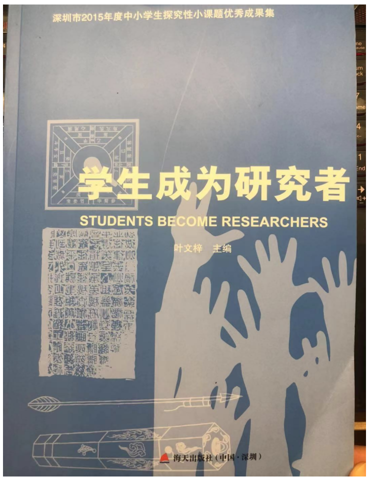
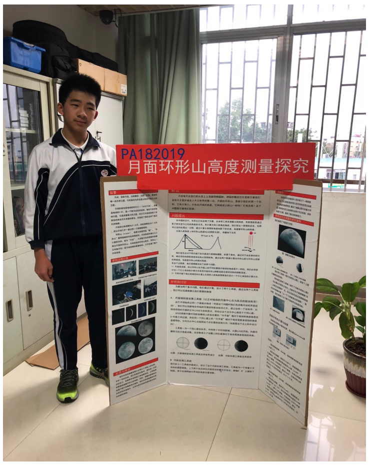
We provide a basic astronomy course, once a week every semester. We help interested students take part in Mini Exploratory Research. From 2015 to 2016, our first Mini Exploratory Research topic *How high are the Lunar craters?* was approved by the Shenzhen Institute of Education Sciences. With their support, students obtain a lot of observation equipment and apparatus for daily observation.

Students have to formally conclude the project one year later, report the research results of the year and write a formal research report. The first research group is composed of four junior high school students. In this process, they collect information and build a knowledge base, which is the important goal of our Mini Research project – to stimulate students' internal driving force, realise the importance of learning, spark their desire for exploration and manage their own learning plans purposefully. For junior high school students, this process of inquiry is a meaningful and interesting attempt. The final report summarised their current course.

In the following years, we also helped students to apply for some other research projects, such as *making a low-cost Solar observation telescope*, and *the research on solar prominence and solar cycle*. The senior high school students tried to design and construct a super small astronomical telescope room with a side length of about 1.5m to place some small observation equipment on the roof of their house for a longer period, and use it for observations anytime and anywhere. The design had a remote control functionality to open and close the telescope and was also waterproof.

During Covid-19, some elective courses were reduced due to the epidemic prevention policy, but we also took a new way to assist students in their project design and research. The use of





remote observatories is one such example. Through the process of active exploration, they have gained beneficial results.

Girls in the Museum – Pursuing Gender Equity in Astronomy

Speaker: Patricia Figueiro Spinelli, Rio de Janeiro, Brazil

Science is a powerful institution for development, but as with any other human endeavour, it is subject to the social constraints of society, reproducing values and practices of dominant groups. The under-representation of women in STEM is one example of such practice. But how can we attract more girls if they keep being discouraged from STEM carriers from a very young age? In this contribution, we will revisit some gender issues in basic science education and share the lessons learned from 'Girls in the Museum of Astronomy' project. The initiative works with the topics of light pollution in science clubs of primary schools relating it with local environmental issues with the ultimate goal of promoting science capital through astronomy.

Talk link: `https://youtu.be/gvp80g4EmZs`

Gender studies show that from the earliest years of schooling, girls are very often not encouraged to like science disciplines, which eventually causes the lower concentration of women in STEM careers [1]. Stereotypes, particularly stronger in these fields, reinforce the idea that women have no equal talent for scientific work.

Therefore, it is important to ask: how can we attract more girls if they keep being discouraged from STEM careers from a very young age? In this contribution, we share some of the lessons learned from the *Girls in the Museum* project running since 2015 [2, 3].

Gender and race/ethnicity in the Brazilian science context
As a starting point, it is important to consider the site where the project runs: a Science Museum in Brazil, in particular, the city of Rio de Janeiro. According to Alves-Brito (2019, p. 1) [4], "Brazil suffers from structural racism and has a strong economy but it is socially unequal, facing several issues regarding its educational, scientific and technological programmes. Over half of the Brazilian population (54%) is made up of people of color, who are the most disadvantaged". Gender imbalance is also a problem that affects Brazilian society as a whole. The combination of these two issues, structural racism and machismo, results in young, black, females being pushed to underpaid and low prestigious (informal) jobs, and consequently, being kept away from career opportunities in science and technology.

The exclusion of certain public in STEM is not surprising if we consider science as part of culture. In Brazil, while dominant (high income) groups of big cities have access to a broad variety of cultural stimuli, medium and low income groups tend to spend their free time doing other types of leisure activities, for instance watching television. If we want to transform society and attract more black and brown girls to the STEM careers, it is important to consider the background of the audience and design activities which not only may raise their interest, but also, help their retention in the STEM system.

The importance of science museums and informal science education

According to the International Council of Museums, by definition *"A museum is a not-for-profit, permanent institution in the service of society (...) Open to the public, accessible and inclusive, museums foster diversity and sustainability (...) offering varied experiences for education, enjoyment, reflection and knowledge sharing."* Thus, science museums should be able to provide significant educational experiences, since they can be a place of discovery and excitement, serving as an environment to appreciate science and culture. It is important to stress, however, that the "context for learning in museums is not the same as in schools or in other institutes of formal education" Hooper-Greenhill (2007, p. 4) [5]. Museum visitors are free to choose the content they engage with, they spend a limited amount of time in the institution (typically 2-3 hours), do not sit at a desk to "acquire" information nor are subjected to content evaluation.

The Museum of Astronomy and Related Sciences (MAST, in its Portuguese acronym), located in the city of Rio de Janeiro, Brazil, is a research institution that brings the wonders of astronomy and its history through exhibitions and education activities to various audiences. The museum's main building and antique domes were the home of the National Observatory, a bicentenary institution that nowadays shares the same campus with MAST.

In Brazil, museum visitors are quite limited. This makes it difficult to use science museums as a tool to engage young people, especially black and brown girls [6]. To improve this, MAST seeks for partnership with the neighbouring schools and the project *Girls in the Museum* is an example of this effort.

Girls in the Museum of Astronomy and Related Sciences

Our project actions dedicated to girls can be classified into two types: short and long-term activities. All actions encourage girls to engage in science and explore scientific careers. The short-term actions are event-like opportunities, where girls can visit MAST for a day and meet female scientists. The long-term actions, aimed at the continuous informal education of small groups of female school students, last for about a year and are structured within the framework of science clubs. A total of 42 students took part in the long-term actions and majority of them were from low income families.

The first edition of the long-term action, entitled "First time scientists", was run from June 2016 to December 2017, while the second one "Astrogirls" took place from March 2019 to December 2020. We are currently running the third edition of the long-term action, with two partner schools, both located in regions of social vulnerability. That is to say, our audience is composed of black and brown girls. The groups were named as "Astronomy's Girls" and "Smooth in the Spaceship".

The three long-term initiatives started with a training in astronomy. Subsequently, while in the first edition, the group developed science education activities to present during the National Science Week 2017, in the second edition, the participants developed a research project related to Solar activity that was presented at the Rio de Janeiro State Science Fair 2019. This year, the two groups are working on the topic of light pollution.

All activities were followed and supervised by three senior female scientists, museum educators and school teachers. The activities ranged from theoretical lectures, workshops and visits to astronomy-related institutions, field trips, and participation in science communication events, as well as, the development of a small research project.

Participating girls are/were subject to longitudinal studies that sought to evaluate the project's actions and monitor possible changes in the attitudes towards science. So far our results point to the importance of not only communicating astronomy but "about" astronomy, highlighting the non-neutral aspects of science, such as the struggles of the female scientists. Thus, presenting science historically and locally is an aspect that contributes to the learning processes of the participants. In addition, the engagement of teachers and family members was of utmost importance to the full participation of girls. The promotion of cultural activities is also a central aspect to the success of action, because it improves the feeling of belonging and helps girls to feel a part of the science and culture system.

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Space for All: A Multinational Study in Astronomy Education

Speaker: Christine Hirst Bernhardt, Maryland, USA

Collaborator: Janelle Bailey, Temple University, USA

This contribution will provide preliminary insights from the 2022 study which included many NAEC teams. Methods include survey and interviews to discover the methods of learning and teaching in primary and secondary classrooms. Data informed comparisons and case studies of international astronomy education efforts in community and formal education. This and the ongoing work by Salimpour and Fitzgerald can provide multinational curricular and pedagogical examples of leveraging astronomy as a "gateway" and inform interdisciplinary approaches to teaching science.

Talk link: `https://youtu.be/syjE_ppW9zE`

Astronomy is one of the oldest sciences in human history; space sciences seek to answer the biggest questions, and encompass technologies which directly impact humanity (Hall, 2013). Astronomy is the only science of collective experience; every learner in every culture enters school having experienced celestial phenomena. They have likely made direct observations, noticed patterns, and posed questions of the Earth and sky. Early exposure to the processes and practices of astronomy can encourage equitable participation and engagement with STEM, which can significantly influence STEM identity formation in girls and underrepresented populations. Restricting astronomy education to university settings is an injustice which furthers the representation gap of women and underrepresented communities in STEM and in global science policy.

Space exploration and technology offer hope and solutions to complex global problems amid the global social, climatic and geopolitical upheaval of the past two years. Astronomy provides limitless opportunities for teachers and students to engage with the nature of science. Astronomy can naturally integrate into existing coursework and leverage students' natural curiosities and interests, which is critical now as we learn to cope with a global pandemic and adapt classrooms for the screen generation.

Shifts in academic standards provide opportunities to incorporate astronomy as transdisciplinary and transformative content. Instead of envisioning science as a silo, we can leverage space as a vessel for the application of scientific and cultural competency, mathematical and language literacy, and global communication. Similarly, research into the contexts and modalities of astronomy education can inform the global education community, yet has predominantly centered on undergraduates. A multinational astronomy education survey in formal education has never been completed. This study will inform future studies and collaborations between educators and researchers, and provide examples of astronomy integrations in coursework and community.

This study was guided by the following research questions:

- How is astronomy utilised internationally to promote STEM in community and school?
- What lessons can be learned from international astronomy education efforts?
- How do international astronomy education efforts attend to equity and diversity?

Methods:
Participants: Participants were recruited through a network of astronomy education coordinators with the International Astronomical Union and social media pages targeting teachers of astronomy. Participants (n=68) were either professional astronomers, formal or informal educators from 20 countries other than the US.

Procedure: Participants completed a survey consisting of national and professional identifiers, a self ranking question of knowledge regarding their national education standards (1 = no knowledge, 5 = highly knowledgeable), and open-ended questions regarding placement of astronomy in the curriculum and to demonstrate fluency with pedagogical content knowledge. Survey data was de-identified, sorted by country, coded and ranked. Selected interview participants were primarily chosen based on demonstrated involvement with national astronomy education efforts. Language barriers were anticipated, and may have inhibited written responses. Three participants were selected based on country and knowledge of national education standards. Semi-structured interviews were conducted via zoom. Participants were asked to discuss the relationship between their national education systems and astronomy, opportunities and barriers to integrating astronomy, teacher education and professional development, and the role of informal learning.

Analysis:
Holistic coding was used to generate comparative themes from transcripts used in cross case analysis. Thematic arrays and comparison tables were used to characterise sub-themes and embedded categories within larger themes. Emergent themes included: education systems, benefits and barriers, national astronomy programs. Multiple arrays were used to compare themes across countries, and to aggregate situated characteristics.

Results:
Preliminary results favour informal, self-directed astronomy learning over mandated curricula. National space agencies, planetariums and informal learning opportunities maintain public interest, demonstrate career growth potential, and promote the "social capital" of astronomy (Japan, interview). Partnerships, collaborations and outreach emerged as an important ingredient to integrating astronomy; some nations lacked significant numbers of astronomers or university programs. Brazil is using astronomy to investigate the age at which students lose interest in science. Several programs demonstrated innovative integration of astronomy and equity: Telescope loan programs provide access and opportunities to poor classrooms and remote communities. In Mexico, astronomy offers social mobility; students build telescopes and conduct observing projects. In Pakistan, a non-profit uses community art and theatre to demonstrate the role of light pollution as a symptom of social problems. Widespread public planetarium programs in Japan focus on our collective human future in space. Barriers to integrating astronomy emerged in every nation, such as grade level text in the National language.

Every nation expressed frustration at the lack of access for teacher training in astronomy.

Discussion and Significance:
Space is exciting, expanding, and can be a force for change. The use of astronomy as a connecting experience can provide examples of community-based sciences, which can be replicated by global educators. Astronomy has the potential to attract students towards STEM, and serves as a natural point of rich integration to other STEM content. Space exploration in early education can be a primary lever for student engagement and enactment beyond STEM courses to career and workforce, which can have ripple effects in national economies. The challenge of teacher preparation can be met by universities, collaborations within and across nations of educators and astronomers, and increased opportunities for teachers to learn.

Future endeavours should scale successful teacher professional development promoting content knowledge, collaboration and content curation. Future work is needed to create quality integrated learning progressions. Future studies should focus on the impact of professional development and collaborations, as well as the impact of telescope loan programs.

Astronomy is our oldest science, and may hold the future of humanity. As one participant pleaded to his national education council, “space is a human right”. Inclusion within the global space economy will propel some nations to inhabit other worlds, while abandoning others. Access to astronomy education should be universal and equitable. This study reveals the limitations and possibilities of bringing astronomy into classrooms.

Sending Seeds in a Stratospheric Balloon as a Motivator in Sciences to Basic Education Students

Presenter: Marcos Rincon Voelzke & Amauri J.L. Pereira, Cruzeiro do Sul University, Brazil

The proposed experiments were the measurement of environmental parameters of flight, such as temperature, pressure and ultraviolet incidence in the stratosphere. Data acquisition took place from an Arduino interface, configured by high school students. Elementary school students selected the most suitable seeds to board the flight, envisioning their future cultivation on Mars, with the aim of releasing oxygen into the Martian atmosphere. The seeds chosen were those of the Japanese Kiri, because this is the tree that releases more oxygen into the atmosphere and its seeds easily adapt to different types of soil and environmental conditions. For the purposes of a future comparative study, the seeds were divided into two groups, with half of them flown in the stratospheric balloon and half not.

Poster link: https://astro4edu.org/siw/p102

Experiments: In 2019 the space science team Longe Laqtve, composed of Brazilian students of basic education, sent seeds and monitored the temperature, pressure and incidence of ultraviolet in the atmosphere from the flight of a stratospheric balloon with the Garatéa-E project (https://youtu.be/Lap1VWlx7WI). Ultraviolet temperature, pressure and incidence data in the stratosphere were obtained from an Arduino Nano interface, configured by high school students and connected to the respective environmental sensors. Elementary school students, motivated by the idea of oxygen release in the Martian atmosphere selected seeds of “Japanese Kiri” (Paulownia tomentosa) since they easily adapt to different soil types and environmental conditions.

Obtained data: The temperature and pressure sensors worked up to the 9,000 meter range, according to the manufacturer’s specification. There is no UV index data on the right face of the Gaussian curve, due to invalid data, probably coming after the balloon burst.

Second phase of the projects: For the purposes of a future comparative study, the seeds were divided into two groups. Half of them flew in the stratospheric balloon and the other half do not. The idea was to plant all seeds in separated flower beds in 2020, but this was prevented by the Pandemic of COVID-19. In 2022, the seeds were planted but none were born.

Project continuity: In 2022 the team classified two other experiments for a future cultivation on Mars. Lichens, collected at an altitude of 1,600 meters on the mountain of Serra do Mar, will be sent, since these vegetables are able to decompose rocks and will be able to help the Earth formation of Mars and also mosquito flower seeds (Gypsophila paniculata) due to the ease of their later analysis in biology laboratories.

City and Learning: TripulanteXXI, Astronomy Route in the City

Presenter: Mónica Martínez Borrayo & Durruty Jesús de Alba Martínez,
University of Guadalajara, Mexico

The introduction of science and astronomy to young adults has had a greater impact through experimental experiences in spaces outside the classroom and linked to common life within their territory and culture. Researching the development of astronomical science in Guadalajara in the 19th century allowed us to propose a route that includes sites with distinctive elements such as the Wind Rose that marks the location of the foundation of the city, sundials, murals (such as El time and hours) and the site where the transit of Venus was observed in 1882, as examples that promote the ability to reflect and experience processes of knowledge in learning astronomy and culture, as a first approach to cultural scientific values of this city.

Poster link: https://astro4edu.org/siw/p103

The project of Crew XXI Astronomy Route in the city, is the result of identifying the astronomical heritage with the evidence that accounts for elements from the mid-nineteenth century to 1970 in Guadalajara, Jalisco Mexico. It is developed to spread the remains, especially with children and young adults, of the importance of heritage, specifically the one that refers to the astronomical theme, due to the risk of disappearing from the collective memory, which it presents due to the principle of not being recognised as part of the cultural heritage and fall into oblivion.

Recovering the memory that lies in the heart of Guadalajara, for young adults and children, reinforces ties in the community by going back to the common past, as a form of recognition of local history itself. Inhabiting the city centre and its recognition takes up the importance from the experience and process actions of meaning on the astronomical heritage, through which it is possible to establish a link with our ancestors, and a way for our children to recover, from the territory, these identity traits as an excursion to astronomical science.

The astronomy route in the city has points referenced on the city map, but also from the city itself with identifications that can guide through the retrieval of information using a QR code. The route also includes activities that introduce a reflection on a specific item of astronomical learning, so that even history and science teachers – and not only with a touristic vision – achieve, at the end of the route, that the "TripulantesXXI" have elements of reflection on the city's own position and orientation, think about what time is and why we measure it, locate objects and link them to a place, a geography, an environment, establish data on patterns, repetitions, generalities and better yet, identify a temporality, a moment, track its history, as well as scientific-cultural contributions. We hope that children and young adults on the threshold of the 21st century will be the future astronomers and guardians of the city's astronomical heritage.

Kottamia Observatory: A Lighthouse for Astronomy Enthusiasts

Presenter: Ola Ali, National Research Institute of Astronomy & Geophysics, Egypt

The National Research Institute of Astronomy and Geophysics (NRIAG), and its observatory "Kottamia Astronomical Observatory" (KAO) have been leading the astronomical research in Egypt. Besides scientific research, NRIAG offers training courses to teachers, pupils, and university students, alongside field trips for astronomy enthusiasts. Almost every week, KAO welcomes organised visits from the public with different ages and backgrounds. Visitors get to learn about astronomy, KAO's 74-inch telescope, and how it works. They also get to enjoy the clear sky and observe different celestial objects with naked-eyes and through small telescopes. We offer special programs for pupils to incorporate their experience with what they learn at school and to expand their frontiers.

Poster link: `https://astro4edu.org/siw/p105`

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The National Research Institute of Astronomy and Geophysics (NRIAG) Egypt; was established in 1839, it is a research institute that follows the Ministry of Higher Education & Scientific Research. It has two main divisions: Astronomy & Geophysics, five departments, 12 laboratories, and around 300 staff members. Besides scientific research, NRIAG has a significant role in community services and the dissemination of scientific culture, especially in astronomy.

One of these services is publishing simplified scientific information on the website and on different social media platforms; Facebook (@NRIAG2), Twitter (@NRIAG2), and Instagram accounts (@NRIAG2). It also has a YouTube channel containing lectures for both amateur and professional astronomers & geophysicists.

NRIAG offers training courses for teachers, pupils, and university students, alongside field trips for astronomy enthusiasts. The public gets to visit the astronomical and geophysical museum, which contains old telescopes, astronomical and geophysical instruments. The museum also includes two clock rooms that have been used for time correction and adjusting artificial satellite observations. Visitors also get to see the Reynolds 30-inch reflector telescope and the solar telescope and how they work.

One of the special facilities of NRIAG is the Kottamia Astronomical Observatory (KAO). It is located approximately 80 km away from the center of the capital "Cairo" over a mountain that rises 450 meters above sea level. KAO was established in 1964, it has been leading the astronomical research in Egypt. It contains a 74-inch telescope, the largest telescope in the Arab world, the Middle East, and North Africa.

KAO researchers know that delivering information to pupils has to be done interestingly, that is why we include experiments, star stories, and other activities during their visits. For example, we offer them the opportunity to use their imagination to explore the stars in the sky and create their own constellations before telling them the actual shape of the constellations. The basic experiment they have to perform is using sundials; we have one in the observatory with a few other small ones for individuals. We do that and more as we want the process of learning astronomy to be fun for them.

Astronomy Education in Volunteer Service

Presenter: Yang Liu, The Affiliated high school of Peking University, Beijing, China & Li Xuedan, The Niulanshan first secondary school, Beijing, China

In 2014, the student astronomy club of the Affiliated high school of Peking University began to systematically organise students of all grades to carry out volunteer services at the Beijing Planetarium. In this process, the school's astronomy teacher cooperated with the exhibition and education team of the Beijing Planetarium, and with the help of the professional interpretation team, the astronomy education and volunteer services were creatively integrated. In the past five years, more than 70 volunteers have been trained to explain the popular science of astronomy, and four of them entered the university to continue their studies in astronomy or physics. Many other graduates also continued to participate in the volunteer service of astronomy explanations during their university studies.

Poster link: https://astro4edu.org/siw/p104

In this contribution, we introduce the method of combining astronomy science education with volunteer services. We demonstrate, how to motivate students to learn about astronomy during early training, how to guide them to transform their willingness to learn in the volunteering process, and how to help them consolidate their interest in volunteering through evaluation after the service and encourage them to further explore the knowledge of astronomy. Finally, we describe an objective evaluation of the practical effects of combining astronomy education and teaching with related volunteer service, so as to illustrate the feasibility of this educational model for astronomy.

Motivate students to learn about astronomy in volunteering training

Since 2014, the school's student astronomy club has been systematically organising volunteer trips to the Beijing Planetarium for students from all grades of junior and senior high schools. During the site service training, teachers are responsible for carrying out site volunteer service training to spread knowledge, where students can get an overview of astronomy. After the training, by adopting a project-based learning approach, students select an exhibition area to learn about the astronomical knowledge related to it, finish writing lecture notes and give presentations under the guidance of their mentors. Then, they pass the school-level examination conducted by the student mentors. In the end, students who pass the school-level examination take part in the official examination for interpretive practice with the participation of professional docents.

Improve willingness to learn astronomy in the volunteering process

During the interpretive services, the students involved can keep deepening their understanding of the relevant astronomical knowledge. Throughout many services, the volunteer docents can, in turn, acquire more astronomical knowledge and provide interpretation services in more areas. Finally, once they pass the examination, they can become student mentors with more experience in service and a more comprehensive knowledge base of astronomy.

Evaluate and encourage further study of astronomy

In volunteering, site service volunteers and volunteer docents work together to provide services and take part in the same multi-dimensional evaluation. Students providing site service have more opportunities to interact with their fellows responsible for interpretations so that the former's interest in further learning can be stimulated. Students involved in the interpretive service and the student mentors can learn from each other during the interpretation practice, so as to deepen their understanding of knowledge and further stimulate their interest in learning astronomy.

Reviewing the data on volunteer service and outlook

With nine years of improvement, more than 800 students have participated in the planetarium volunteer service, of which over 300 have passed the school-level examination and nearly 100 of them have become volunteer docents at the planetarium. Among them, more than 70 students have grown to become student mentors, and six of the dozen student mentors who have graduated from senior high school have gone to different universities and colleges (e.g., Peking University, Cornell University, Wellesley College etc.) to continue their studies in astronomy or physics. Other graduates also continue to volunteer as astronomical docents.

Overcoming the Hurdles in Imparting Astronomy Education in Schools

Presenter: Vaibhav Trivedi, Fergusson College, Pune, India & Suresh Parekh, Department of Physics, Savitribai Phule Pune University, India

Here, we discussed our research and answers to the astronomy education issues that students face. We conducted a teaching experiment at a local school. We first presented astronomy in a standard manner. Later we presented the same ideas using working models, and exhibits and using less mathematical content. When we performed an identical assessment on students, we saw that their analytical abilities to comprehend the problems had greatly improved. The students quickly achieved the much-needed visualisation skills compared to a standard way of teaching. The same students now have no trouble solving astronomy-related mathematical problems that they previously had difficulty with. We visited many schools and got similar results. These methods enhanced their learning process.

Poster link: https://astro4edu.org/siw/p106

We carried out different outreach initiatives in local schools in Ahmedabad through our Astronomy Club, ASTRONOMICA, including workshops, talk series, astronomical observations using telescopes and sun filters, and explaining astronomical ideas using models. This summary includes our conclusions based on our experiences.

Challenges in cultivating curiosity among school students: We have faced a few hurdles, which we believe are the reasons for the lack of astronomy education in schools:

- The involvement of mathematics: School students show little interest in the mathematical side of astronomy.
- Lack of fundamental physics knowledge: Many students lack an understanding about various physical concepts and thus find it difficult to grasp different astronomical phenomena.
- Lack of equipment in schools: Majority schools do not have access to a telescope. They even lack basic demonstration models, which can help explain simple concepts.
- It is difficult for teachers to manage academics, along with extra astronomy activities.

Solving the hurdles in Astronomy Education: Firstly, we need to examine the level of physics

  

Outreach activities done in various schools and equipment of our astronomy club

knowledge for students from different classes. Astronomy clubs should be established in schools and astronomy should be introduced as an activity for students. Below are some points which we concluded from our strategy while studying astronomy education. These steps help to achieve a better impact from the outreach activities:

- We found that students understand and communicate better when the mathematical aspects are diluted.

- We developed various models like the solar system model to help with explaining events like eclipse & occultation. This also enabled developing analytical & problem-solving skills.

- With the help of smart television, we presented many animations of astronomical events and objects like the occurrence of an eclipse, what a black hole looks like, how it feels to be on mars, etc. This improved their visualisation skills and nurtured their curiosity to understand the concepts.

- We also proposed that schools should try to arrange for at least one telescope for students.

Role of astronomy clubs in school education: Majority of the astronomy clubs have equipment like telescopes and filters etc. They can prepare models which will be beneficial for demonstrating various phenomenon to students. Clubs should encourage students to participate in International Asteroid Search Campaigns and provide exposure to school students and host similar events at the local level. Clubs can organise various activities like public talks, hands-on workshops, stargazing activities, observing astronomical events etc. regularly in schools to introduce and promote astronomy education in schools. We tested each student by asking them questions on several factors listed in the table below before and after we implemented our astronomy education approach, and the results were astounding.

Results (out of 10) of the test on 100 students to check their performance before and after implementing our methods

Before				
Problem Solving Skills	Curiosity	Visualization	Analytical Skills	Topic Understanding
4	6	3	5	6
After				
Problem Solving Skills	Curiosity	Visualization	Analytical Skills	Topic Understanding
8	9	8	8	10

A Hands-On Project about Instructing High School Students in Practice of Astronomy Science Research

Presenter: Guimei Liu, Shanghai Astronomical Observatory, CAS, Nanjing, China

Collaborators: Wenwen Zuo and Ruqiu Lin (Shanghai Astronomical Observatory, CAS)

The Astronomy Educational Base of Shanghai Astronomical Observatory (SHAO) was established in 2016, through collaboration with high schools in Shanghai metropolis, providing a platform for high school students to practice astronomical investigations. With the advantages of rich astronomical resources in SHAO, various projects have been developed to help high school students understand frontier astronomical achievements and the ways researchers conduct their work. Through the hands-on activity of probing star colours, we attempt to deepen students' understanding of the star colours in terms of photometric measurements and the stellar interior properties, cultivate their ability of information retrieval, and also enhance their public speaking and report writing ability.

Poster link: https://astro4edu.org/siw/p108

Cooperation between Shanghai Astronomical Observatory (SHAO) and high schools in Shanghai metropolis provides a practical platform for high school students who are interested in astronomy to practice astronomical investigations. Various programs have been developed to help high school students understand cutting-edge astronomical achievements and how researchers conduct their scientific work. Practices in various fields of astronomy would greatly stimulate students' curiosity and expand their horizon.

The teaching model of the program is a combination of lectures and hands-on activities. We all have a general overview of the program to give students a sense of how astronomers conduct scientific researches and arouse students' interests in astronomy. Then various research groups introduce astronomical background knowledge and practical skills, respectively, so that students can select topics according to their own interests. Next, each project provides personalised teaching and hands-on activities for varying levels for students. Students make periodical reports at different stages (proposal, middle stage and task completion).

Our project belongs to the stellar observation topics, intended to instruct a group of high school students to explore the stellar colour based on the SDSS database (http://skyserver.sdss.org/dr17/). Starting from the visual inspection of star 'colours' seen in the full variety of SDSS images, students make comparisons with the color-index parameters of several different stellar types, taking efforts to better comprehend relevant astronomy definitions of stellar colours. Furthermore, given the SDSS ugriz images, students perform aperture photometry analysis to derive the magnitudes of the stars in different bands and compare with the published SDSS magnitudes. For advanced exploration, we guide students to calculate approximate temperatures of target stars by fitting a blackbody spectrum.

Discussion summary

The research interests of the speakers of the sessions on Astronomy Education Research included Project Based teaching, building knowledge, analysis of training sessions, and investigation of cultural diversities. They use theories based on socio-constructivism, enaction, and motivation. The research projects that have been presented went from case studies to large-scale surveys.

Discussions in all sessions have been rich: The meaning of conceptions (mis-, alternate) and their link with mental models have been scrutinised, in relation to the skills that may be learned using astronomy in school; the impact of astronomy on society has been discussed in connection with the link between culture and the community of people working in astronomy education.

Mental models and conceptions: Most participants agree that the word “alternative model” has to be preferred to “misconception”, even if “misconception” is often used in many research papers. Indeed, conceptions may be described as a “coordination of pieces” that constitute the “mental model” (talk by M. Ubben) of learners. It is important to be aware that mental models reported on in research are never individual models, but are a reconstruction made by the researchers through interviews, tests, etc.

Those mental models, though unconscious, arise very early through all perceptions lived by learners. Even if vision is the only sense that seems to be used in the context of astronomy, mental models of astronomy objects also involve emotions and actions. The use of an immersive environment, with 3D models and sound records, is possible today. Accounting for all senses, and even “augmented” senses, may change the learning/teaching for the better. Indeed, a learner may then build new pieces on those perceptions, until they fit into a coherent and scientific model (in the ideal case). Knowing mental models helps teachers to accompany the learner along this path.

The specific case of the movement of the Sun and Earth in geocentric and heliocentric frames has been discussed (talks by E. Blanquet, M. Cole, and E. Rollinde). The mental models evolve from a direct perception that favours the terrestrial frame to the paradigmatic pressure by society/school in favour of the heliocentric frame. The ability to change our point of view from one frame to another, and then accept both frames (in accordance with the principle of relativity), is still an educational challenge.

The use of images with “alternative conceptions” (or even wrong ones in some manuals, TV shows, etc.) has been explored. Images and schema cannot account for the complexity of the scientific models. Even spoken language has limitations and ambiguities compared to mathematics. It may then be very useful to introduce images with “alternative conceptions”, observe those and discuss their limitations by comparison with observations, predictions, and scientific models. Yet, one must be careful that, while developing a critical spirit, learners keep trust in the advances of science.

Astronomy for schools: All participants understood astronomy in school as a means to promote STEM, and alleviate the anxiety that mathematics creates for many learners. Astronomy inspires students, more than seeing equations… One piece of advice is to use astronomy for amazing stuff to teach and be careful not to teach astronomy only because it connects to other subjects.

Specifically, the long-distance objects make it an excellent context for learning in an unusual environment, and hence unusual perceptions and experiences.

It also appears that one of the main skills that may be worked out through astronomy is spatial thinking and spatial cognition, and more specifically “mental rotation” (talks by H. Lewis and M. Cole). The understanding of the phases of the Moon is a clear illustration of this skill. Both teachers and students need to develop the ability to do “mental rotation”, which may sometimes be more discriminant than the lack of astronomy knowledge.

Hence, the evaluation of content and methodology of teaching in curricula, in a classroom, and in a teacher training session is obviously an important topic (talks by C. Hirst Bernhardt, L. Rodrigues, and S. Jafari). Such an evaluation must include knowledge in astronomy, didactics (such as learners’ mental models), and pedagogy; and then ability in spatial skills.

In the context of evaluation, the use of questionnaires that do not focus on astronomy only and by symmetry the use of astronomy context in maths questionnaires to provide motivating situations have been discussed in relation to the talk by S. Buxner.

Astronomy and society: Participants have emphasised the need to embed astronomy education in local culture and not as a stand-alone subject. This implies links with social problems, such as light pollution, gender issues, etc. (talk by P. Figueiró Spinelli). One also has to take care of local specificities in the proposed astronomy situation (such as the differences between the sky view in the Southern and Northern hemispheres, or the reversed seasons).

Connections among different communities: The need to connect different communities has been often expressed (talks by Z. Hu and I. Costa). A common connection is made between teachers and astronomy researchers in the follow-up of projects. It has been noticed that astronomy, science, and maths education researchers must be more engaged in school projects. About training programs, it has been advised that the three – teacher, astronomers, and education researchers – are present in the design of the training session.

The need for stronger connections with museums has been emphasised too. This would ease the dissemination to teachers who are the large-scale multipliers through schools.

Astronomy Education in Practice

Teaching Astronomy in Primary Schools: How, Why, and in What Context

Session organisers: Sara Ricciardi (OAE Center Italy), Silvia Casu (OAE Center Italy), Alessandra Zanazzi (OAE Center Italy)

Session overview

In this session we will pose some questions relevant to Astronomy and Astrophysics in the primary school, considering pupils from 6 to 12 years old, and hopefully we will also try to answer some of those questions together.

How should learning be? How should scientific learning be? What are the best practices to open up to children a scientific point of view about the natural world? What could be the role of the sky and the night sky in developing scientific citizenship? And then how can we encourage those practices in schools worldwide?

In this session, we will listen to different voices of teachers, practitioners, educators, and National Astronomy Education Coordinators (NAECs) from many countries; we will discuss how, through different points of view and perspectives, we can contribute to forming a new generation of young adults able to fully understand our world, so entangled with science and technology development.

Astronomy and Astrophysics in schools could be powerful instruments to build not only scientific literacy but scientific citizenship; it could help us understand the uniqueness of our planet and to understand that our community, the earthlings need peace and kindness to prosper.

TALK CONTRIBUTIONS

Three Little Steps in the Sky: From Conventional Teaching to Cooperative and Meaningful Experiences

Speaker: Franco Lorenzoni, Movimento di Cooperazione Educativa, casa laboratorio di Cenci, Italy

This contribution describes three experiences that refer to activities developed as part of the research / action project "Between sky and Earth", experimented together with girls and boys both during extra-curricular workshops and in the school context. Each "step" opens a reflection about the learning that builds knowledge from experience, its possibilities and its meanings.

Talk link: https://youtu.be/VovoA5DNpjA

In this contribution, we describe three experiences developed in the research-action project "Between sky and Earth"[1] and tested with boys and girls in extracurricular workshops and the school context. Every experience brings a new reflection on how deeper and more meaningful learning occurs when knowledge comes from direct and meaningful experiences.

The first step is a story of activity aimed at reestablishing a relationship with the sky and is about daylight observation. Looking at the Sun from a fixed position, using a simple eyelet on top of a long stick, we start recording the Sun's position at regular intervals (e.g., every hour). To make the observation visible, we use coloured threads and rods. After a few hours of observation and recording, we discuss what the sun-catcher is showing us: the Earth's rotation on its axis, the partition of this round angle into wedges, and finally, a sense of wonder when the kids discover from this observation a geometric world. An experience like this will not only deepen disciplinary knowledge but also take the kids to the re-appropriation of this knowledge and contribute to understanding the original idea beyond geometry: a measuring instrument of the world.

The second step is about the Earth and the fundamental question – that we have from childhood – about our planet's shape. Even the most passionate lecture sometimes is not so meaningful

[1] Some of those ideas are illustrated in the book "With the sky in the eyes" by Franco Lorenzoni, La Meridiana editions (in Italian). Nicoletta Lanciano has collected a large number of instruments for astronomical observation, partly historical, and partly reinvented during the research she animates, in the volume "Instruments for the gardens of the sky" (in Italian)

for some boys or girls. In such cases, we then try again to start from a practical experience, hand-building possible models of the Earth starting from the only observation that man had before the space age: the observation of a moon eclipse. From observing this phenomenon or a picture of it, we notice that whichever shape the Earth has, it projects a round shadow on the moon. We then start revising all the models proposed, and we see what kind of shape they cast. We realise that the spherical shape is the only one that really works. Once again, first-hand experience guides to deeper and more meaningful knowledge in a learning community that learns to build knowledge.

The third step comes from a re-appropriation of the classical globe. It shows and makes tangible a pretty complex idea: on the planet Earth, there are at the same time different times of the day - the time zones. This activity is called Globolocal (Localglobe) because the globe is fixed at the local position of us observing. We take it off its support and put it like this: the top of the globe is the place from where we observe, and the north pole is oriented north. In this way, the globe in my hand and the Earth under my feet are oriented in the same way in respect to the Sun; kids can visualise in real-time the shadow and light zones of the globe that correspond to the light and shadow zones on the planet Earth. We can then work on the globe, marking dawns and sunsets to the passing of time and once again measure the movement of the Earth on itself. In conclusion, building, manipulating, and using objects to build a relation to the real world can produce huge discoveries in the classroom; we can rebuild together a piece of knowledge but also learn to develop good thinking together.

STEM+A@Astronomy:
How to Motivate Students to Learn Astronomy

Speaker: Exodus Chun-Long Sit, Starrix Hong Kong, China

Developing future skills are crucial for students to integrate knowledge with an innovative thinking mindset. However, subjects taught are generally separated in mainstream schools. Some students may lack the experience to overcome cross-disciplinary problems when they are facing their future society. Astronomy, as an interdisciplinary science, can be a link between different disciplines, building science literacy. The talk will introduce an interdisciplinary project called STEM+A@Astronomy. It aims to cultivate students' learning incentives and curiosity about the night sky through experiential learning. It could apply to modular lessons in formal education and interactive activities in public education to provide an intensive learning experience for students in their daily life.

Talk link: https://youtu.be/NRBl0oxm7hY

Traditionally building a customised telescope with a unique design usually requires some engineering techniques, such as a DIY maker or computational background for designing and making a prototype through digital 3D printing. For science popularisation, these would be a barrier for astronomy enthusiasts who may not have a related scientific background or 3D modelling experience. However, some entertainment toys could be helpful as educational tools for making telescope prototypes with creativity and low-tech requirement. Building blocks, such as Lego bricks and Nanoblock, could be used to build a telescope in a more accessible way. It will be more user-friendly if you can customise your telescope design with lenses installed in different shapes and colour combinations.

Teaching astronomy by building blocks can help educators and science communicators to visualise complicated structures of space suits, allowing participants to engage with hands-on experience and multi-sensory interaction (Fig. 1). There are existing block sets in the marketplace for science communication demonstration and educational purposes, such as Apollo Saturn V Rocket, Lunar Lander, and International Space Station. But this astronaut's space suit model is unique, in the style of Jason Freeny's anatomical sculpture (`https://jasonfreeny.com`), and allows the participants to understand the complicated structures of space suits. Rarely can students see the actual space suits used for space missions, not to mention how hard it is for them to understand how a space suit works, and its internal mechanism.

Building blocks can allow educators and science communicators to build a 3D model feasibly and freely without the requirement of scientific background or technique-operational experience. Targeted learners will also be able to contribute to the learning experience of building blocks (3D prototypes) based on their imaginations and creativity, allowing them to modify their designs and motivating interactive learning progress through peer evaluation and inspiration from design

Figure 1: Teaching astronomy by using building blocks is helpful to visualise complicated structures of space suits, allowing participants to engage with hands-on experience and multi-sensory interaction.

Figure 2: This reflecting telescope model is built using blocks and based on the actual scales of the telescope with different telescope equipment. It is generally used to demonstrate the procedures and important reminders of setting up a telescope.

Figure 3: Using blocks to build a telescope allows flexibility and creativity in structural design. This refracting telescope Mark I was built in a square tube shape as a prototype of the experiment of using Lego blocks to build a telescope.

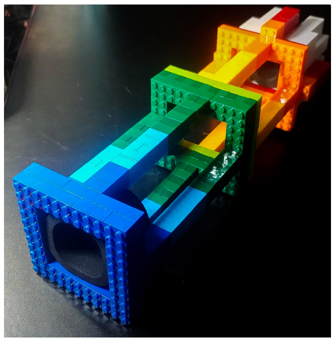

Figure 4: This refracting telescope Mark II is a modified version of a telescope built with a Truss Tube. It is encouraging to try different shapes and diameters during the construction of Lego blocks. It allows you to evaluate the quality of observation and make the adjustment easily just to remove the unnecessary part of blocks to make them lighter and better designed, during the design thinking process.

thinking engagement. There are more hands-on examples, demonstrated in the figures above.

Observing the Sky in Astronomy Education: Building Benchmarks

Speaker: Gleice Kelen Dornelles Costa, Inter-Unit Post-Graduation in Science Teaching, University of São Paulo, Brazil

Collaborators: Antônio Carlos da Silva, Raquel Gomes dos Santos and Cristina Leite (Inter-Unit Post-Graduation in Science Teaching, University of São Paulo)

The practice of sky observing in basic education can produce good results, but may be hindered by some factors. To understand which aspects are essential for its realisation, we conducted a literature review, based on publications in astronomy education, which allowed us to build elements and organise them in three moments, allowing the necessary planning for its success.

Talk link: https://youtu.be/5ddRWltSA0g

The activity of observing the sky dates back to Antiquity and is one of the ways in which knowledge in astronomy is acquired. According to researchers in the field, astronomy was "born" from the observation of the sky with the naked eye [1] and progressively established to meet the social and religious needs of humanity [2]. Moreover, the observation of the night firmament can lead to the realisation of the beauty inherent in this scenario and is capable of arousing feelings such as enchantment and fascination [3].

The presence of sky observation in basic education is advocated by different researchers as a didactic strategy to broaden the perception of the astronomical environment and of the phenomena that are part of everyday life. These authors indicate that the feelings and sensations caused by celestial phenomena in students can be used to spark interest in science classes [4]; that teaching only using textbooks does not provide the construction of spatiality [5, 6]; and that the teaching of astronomy should start by observing the sky [7]. However, the success of these activities requires careful planning, considering that sky observing activities demand time (duration and timing of the activities) and spaces that are outside the traditional school system, especially the Brazilian one, in addition to the need for the right atmospheric conditions. Therefore, the formulation of activities of this type requires that some parameters are established, and for this, it is necessary to identify and understand the fundamental elements for the composition and realisation of the activity in a school environment.

Materials and Methods:
With the intention of building references that support the creation and analysis of sky observation proposals, a set of elements was developed from a bibliographic review, with a qualitative approach, guided by Bardin's content analysis [8]. Astronomy education publications that involved didactic proposals or reports of celestial observation activities were selected. For the bibliographic survey, we searched for research published until the year 2015 in the electronic domains: Latin American Journal of Astronomy Education (RELEA) and the Bank of Theses and Dissertations on Astronomy Education (BTDEA). Other materials from the research area of astronomy education were added to the corpus for analysis, such as those of Néstor Camino and Nicoletta Lanciano, as long as the publications discussed, described or reported observation proposals, or even books oriented celestial observations, such as the publications of Romildo P. Faria, Rodolpho Caniato and Ronaldo Rogério de Freitas Mourão. With the selected materials, deeper readings were performed, identifying how the sky observation activities were designed, looking for similarities and/or differences.

Results and discussions:
With the data, it was possible to structure categories that cover three major moments: before, during and after the sky observing activity, which correspond respectively to the stages of pre-observation, observation and post-observation. Pre-observation is the moment when the student is prepared to carry out the activity. It is during this phase that the students' previous knowledge is gathered; to define what will be observed and the concepts involved; to define the focus of the investigation, the period of the day in which the observation will occur and its respective duration. During the observation, data collection takes place. This phase includes the criteria of strategies to observe and follow the stars or phenomena, such as instruments, records, measurements, and references. Finally, the post-observation phase is the moment to calculate and analyse the measurements recorded in the previous phase, and to resume and discuss the concepts based on what was observed.

Considerations:

Therefore, the frameworks built in light of the elements obtained in astronomy education research can be systematised into three major steps – Pre-observation, Observation and Post-observation – and, in this way, support the sky observation activities, allowing to give meaning to what is learned and leading the students to broaden their view of the sky as it keeps them active from the pre-observation phase until afterwards. In addition, these elements make it possible to build didactic proposals, to analyse existing proposals, and can also help teachers plan these activities. However, the structuring presented here should not be understood as a mandatory sequence, because each class, each school and each teacher is immersed in a universe of specificities that may go beyond the elements discussed here.

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Classroom Activities Related to Equinoxes and Solstices: Examples From the Astronomy Day in Schools

Speaker: Akihiko Tomita, Wakayama University, Tokyo, Japan

Equinoxes and solstices are not only astronomical events, but they are also important phenomena connected to cultural events in various regions, making it a good gateway to the world of astronomy and science for teachers. The Astronomy Day in Schools (ADiS) project is organised by the sub working group (WG) of ADiS, under the WG of Astronomy Education Research & Methods, Commission C1, IAU. The project website is hosted by the National Astronomical Research Institute of Thailand. On the website, the project has called for records of practice related to equinoxes and solstices. The project has also organised online meetings on occasion of the equinoxes and solstices. We will introduce examples of the records, and we hope this will help develop a network of students and teachers.

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

With the Astronomy Day in Schools project, we want to help schools around the world share their astronomy education practices and interact with each other. Please visit our project website and do share short videos or photos of your practice. We would also like to maintain a repository of your valuable inputs, which we are now developing, to help create a network of teachers and students all over the world.

Many activities took place in different countries. For example, the middle school students in Romania were given 60 minutes after school to represent the autumnal equinox by painting. On this day, day and night are 50-50 for the entire planet. The resulting paintings made by students were so impressive and beautiful that it was hard to believe that these are the works of 12 to 14 year-old students. At the autumnal equinox of 2021, students tried to determine the latitude of the observation site by measuring the altitude of the Sun when it was due south. This activity took place in Puerto Rico and Chile.

The Astronomy Day in Schools project is not just a repository of teaching material but it aims to create a strong network of students and teachers by organising quarterly live programs for students and teachers, around the time of March equinox, June solstice, September equinox, and December solstice. We started a pilot program in 2021 and have communicated various practices by teachers and students from many countries.

On September 30, 2022 we held another event during the September equinox, which is the autumnal equinox in the northern hemisphere and is also celebrated as Mehregan, one of the four important ceremonies in Iranian calendar. Several classroom activities from Japan were introduced. An elementary school teacher took photos of the sunset location changing every day and using these photos, students discussed the changing position of the sunset. Many activities for students organised by the National Astronomical Research Institute of Thailand were introduced, including building a portable planetarium. Japanese high school students who joined this live program were also working on planetarium building as the school club activity. It is likely that high school students and the National Astronomical Research Institute of Thailand will exchange information on the portable planetarium in the future. This is one of the great results of this live program.

From Iran, a series of photos of sunset before and after the autumnal equinox were presented, taken by the teacher and then by the students. This is teaching material to help students understand that the angle of the sunset is related to the latitude of the observing site, that the angle does not change from day to day, and that the position of the sunset changes from day to day. The educational environment in Iran is currently threatened, especially for women and girls. Iranian school girls are also standing up against the political power over women and girls. In response to the domestic protest movement, the internet is currently not freely available in Iran. Despite this, Iranian teachers managed to connect to this live program to introduce the material and the activities of their students. It was a powerful message from the Iranian teachers to continue education, to continue education network with the world, no matter what happens.

From Bulgaria, Ivo Jokin, NAEC Bulgaria, introduced the student activities and teaching materials shared at the European Research Night. Ivo encouraged the participating Japanese teachers and students to join the various campaigns organised by European teachers. It seems that the Japanese students have gained a new and unique window to the world. From Romania, there were presentations from nine schools. They introduced Romanian events and cultural aspects of the autumnal equinox, as well as what goes on in their schools. They told us very enjoyable stories and cultural customs, such as they do not pick the last fruit from the tree in the harvest to thank mother nature on this day, and they do not scold their children on this day. Many students joined the live program along with their teachers. From Egypt, Dr. Somaya Saad of NAEC Egypt, gave an introduction to teacher training for female teachers.

This live program was recorded and will be edited and made available to the public. The online program was two hours long. There were many students and teachers present. The goal was to create a bridge between teachers and students. In order to have this kind of an exchange, the world must be at peace, and we must be able to keep in touch with each other without anxiety.

Iranian students have given many presentations at previous online meetings. Together with their teachers, they have also created national and international networks. The fact that Iranian students were not able to participate in this time shows that our activity and astronomy education in general are deeply affected by the political situation. We hope that Iranian women and girls will be safe and that their pursuit of academic, cultural and human rights values, together with their network with the rest of the world, will open a new era for Iran and the world.

Syrian Astronomical Association: A Trip of Success

Speaker: Turkieh Jbour, Syrian Astronomical Society, Syria

We are highlighting the Syrian experience of educating children on the sciences of astronomy and space during war and crises. As we always considered the sky our safe and sacred place during war, observing it and reading about its planets and stars helps to forget all about the sound of the bullets. And lets the Syrian children be well aware of how life will keep going by learning and working hard to achieve our goals. We are talking about our experience since the very beginning of the Syrian Astronomical Association and how we worked on astronomy outreach for the whole society, focusing on educating children. We worked on introducing astronomical sciences in a fun, simple and easy way based on thinking out of the box, by giving real life examples of scientific information, and through experiments and games which consolidate the information. We cooperated with the national curriculum development center to introduce astronomy in the curriculum as part of some subjects like geography, biology and physics starting from primary school until high school. Since the establishment of the Syrian Astronomical Association in 2005 we aimed to introduce astronomy and space science in every house in Syria. We are working to cooperate with every national, Arabic and international institution to make the future a better place for every child on this Earth, to live safely under one sky. The Earth is for everyone and the sky is for everyone.

Talk link: https://youtu.be/OePwN_Ss76w

The Syrian astronomical Association was established on 31/8/2005. Its goal was to do astronomy outreach in the Syrian society. At the beginning, its name was Syrian Amateur Astronomers Association. It started its astronomy outreach activities with public stargazing events and regular lectures at many cultural centers for all kinds of social classes, making astronomy and stargazing accessible for everyone. It also made sure to participate in most of the Arabic astronomical conferences and events like the Arabic conference in 2006 hosted by the SAA and an international conference in 2010. The association participated particularly in the Arab Union for Astronomy and Space Science conferences, and youth conferences in many countries like Algeria, Tunis, Jordan, Oman etc.

Through its journey, the association worked with many of its members to build telescopes and CCD cameras. From the very beginning of the associations' history, the SAA focused on educating children about astronomy, holding a special program for them and made sure to visit schools and educational centers all over the Syrian governorates.

2009 was a very important year for us, since it allowed expanding the association activities both in the Arab world and internationally. It was the real beginning of the association when it participated in projects that were proposed during the international astronomical year. Along with participating in “100 hours of astronomy” event, universal diaries, and “She is an astronomer” project that aimed to outreach astronomy between women and girls, the association also worked on “The little astronomer” project. We ended up creating a special page for the little astronomer in our website.

Through these events and activities, the association had worked on placing telescopes on the streets, restaurants and public places and organising many trips to the other Syrian governorates and introducing people to its work. However, it was not enough nor satisfying to organise events and lectures alone. The goal was much bigger than that, it is to work on reviving the Syrian astronomy heritage by trying to renovate the sundial of Ibn al-Shatir.

Since the beginning of the crises in Syria, the conditions have changed. The events are limited and more restricted. It is difficult to travel to other governorates and the international restrictions limit our interactions/collaborations with the international community.

Despite all the difficulties, the voice of the bombs, the view of our destroyed country, we tried to open a new window and see the world from it again and even let it see us. “In one orbit they swim" a program prepared and presented by Dr. Muhamad AlAssiry, the association’s president since 2013, reached the episode 401 last week.

In 2012, the name was changed to the Syrian Astronomical Association SAA. We participated in the contest that the IAU held for naming exoplanets and we succeeded in naming the planet that was orbiting around the shepherded star “Tadmor” after the Syrian historical city (palmyra in English) that was facing war at that time. We also named one of the asteroids “Al Tantawi” after a Syrian astronomer.

2017 was the year of a big leap in our journey, we build the Syrian astronomical observatory despite the difficulties and lack of resources and opened it to the public. We also organised activities for the blind and people with other disabilities. The observatory contains a lecture hall, 3D cinema, and hologram rooms in addition to the dome and an open space for observing nights.

We also established many sections in the other Syrian governorates like Aleppo, Homs, Hama, latakia, Masyaf, Tartus and Rif-Dimashq. We revived the little astronomer program through the quarantine in 2020. During Covid-19, we started teaching astronomy using WhatsApp; encouraging children to use their imagination and better understanding their surroundings. We also taught them the proper way of searching for new information on the internet and helped them write simple articles that were age appropriate. We continued with our activities and events after the quarantine period. We also made a schedule for new volunteers to master preparing and presenting lectures.

The association has been participating in local science conferences and events. For example, the Arabic conference for science history for the Arab that took place in Aleppo. To encourage children who are interested in astronomy we prepared a special national television program called “the scientist of the future” to increase their passion for astronomy. We were able to introduce astronomy to the curriculum in collaboration with the National Curriculum Development Center.

We also launched a contest between children for the best scientific article and best drawing representing the state of the Earth during Covid-19 and the global warming. This helped teach them the importance of keeping our cities clean and using clean energy resources and to also raise awareness about climate change.

Bringing Astronomy and Science to the Public Using “The Velogyaneshwari” Bicycle

Speaker: Rupesh Labade, Inter-University Center for Astronomy and Astrophysics, Pune, India

Collaborators: Maharudra Mate and Samir Dhurde (Inter-University Center for Astronomy and Astrophysics, Pune, India)

Science and astronomy subjects are taught in schools only theoretically due to the absence of teaching aids, costly materials, and availability. So we introduce here the concept of “The Velogyaneshwari” (The Bicycle science). Its main objective was to connect students with basic concepts of astronomy and science. We did a lot of simple observational experiments using low-cost material and using android phone applications, which are attached to this bicycle. One can simply take this bicycle to schools, playgrounds, gardens, etc., and demonstrate experiments attached to it. These low-cost experiments helped students understand science as a whole process while reconnecting them with the observation of natural phenomena.

Astronomy has a great potential to awaken children’s curiosity for science and improve their scientific literacy. However, it has a small presence within the school curriculum worldwide and is mainly descriptive and restricted to Earth-Moon-Sun topics. Currently, the interdisciplinary science of astronomy (or space science) is seriously under-taught in most primary and secondary schools. Instead, the core sciences of physics, chemistry, and biology are typically emphasised. These science subjects are mostly taught in schools theoretically due to the absence of teaching aids, costly materials and availability.

Purpose: So we introduce here the concept of “The Velogyaneshwari” (The Bicycle science). Its main objective was to connect students with basic concepts of astronomy and science, showing that it is possible to locate yourself spatially, calculate the size of the Earth or even estimate the size of the Sun and observe the night sky. Everything is achieved through observation of nature, basic geometric concepts and some low-cost experiments attached to this bicycle.

Figure 1: The Velogyaneshwari: wheels of knowledge

Methodology: We did a lot of simple observational experiments using low-cost material and using android phone applications, which are attached to this bicycle. One can simply take this bicycle to schools, playgrounds, gardens, etc., and demonstrate experiments attached to it. Also, students enjoy this kind of learning using their own bicycles. Low-cost instruments like a magnetic compass, bottle telescope, Windmill generator, geoboard etc. are attached to this bicycle so that students can learn science anywhere anytime.

These low-cost experiments help students understand the science as a whole process while reconnecting them with the observation of natural phenomena. They use knowledge of different areas and make a connection between astronomy and basic sciences. To their surprise, they discover that astronomy and maths are interconnected. Our experience shows that doing this kind of activity can help students improve academically in many subjects and change their idea of scientific methods.

List of Experiments that we can perform with Bicycle:
Gyroscope, Pin hole projector, Umbrella constellation, Windmill Generator, Solar power lamp, Pedal power generator, Sound Horn, Newton colour disc, Centrifugal force, Star dial, Projectile motion, CD spectroscope, sundial, Brain cap, Geoboard, Gas law, Cycle valve tube geometry, Constellation map, Bottle telescopes, Stargazing using astronomical lasers, Concave and Convex mirror, Cycle gear mechanism, Cycle geometry, Solar cap, Bottle rocket, Stethoscope, Solar Goggles, Foldscope, Magnetic Compass, Optical Illusion pattern, Experiments using android applications, and many more.

Results: The Velogyaneshwari seems simple at the first glance but helps to introduce very difficult concepts. This promotes motivation for students and teachers, practical demonstrations, and models and analogies in teaching. It helps to get a deep understanding of the process of learning through a hands-on approach. It helps students feel like the protagonist of their learning process. It also promotes the highest comprehension of students and is useful in all the countries: with different degrees of technological advancements. It can be used by young as well as experienced teachers since using a bicycle is also good for a healthy life.

The approach involving students also creates an even deeper understanding of astronomy itself. Moreover, the fact that the students not only understand the topic, but build their own materials attached to their own bicycle and makes it the Velogyaneshwari, which does foster creativity, resourcefulness, and the experience and gratification is empowering.

Resources:

- www.arvindguptatoys.com
- www.stellarium.org
- https://phyphox.org
- https://www.real-world-physics-problems.com/bicycle-physics.html

CLEA's Propositions for Introducing Astronomy into the French "Science Plan for Primary School"

Speaker: Frédéric Pitout, Midi-Pyrénées Observatory, Liaison Committee between Teachers and Astronomers (CLEA), France

French education authorities have (finally!) realised that primary school teachers are not properly trained to teach science. To overcome the issue, they have initiated a "science plan for primary school", which consists a series of teacher training sessions focused on science, as well as teacher support. They also issued a call for participation in this science plan. In this contribution, we detail the notions of astronomy present in the French primary school curricula, how they can benefit other topics (maths, Earth science, French, history, etc.) and how the Liaison Committee between Teachers and Astronomers (CLEA in French) responded to the call for participation in the science plan.

In most French primary schools, there is a single teacher per class who teaches all topics including science, technology, engineering, and mathematics (STEM). Yet, most of them are quite uncomfortable with teaching STEM. The reason is that the majority of primary school teachers (∼80%) studied literature or human sciences, but not STEM at a university level. Another issue is the over-representation of women (84%) among primary school teachers. The consequences are the following:

- Teachers feel lost and lack self-confidence when it comes to teaching STEM subjects,
- STEM are not properly taught in primary schools,
- The probability is very high that pupils only have female teachers not knowledgeable about STEM over their school years,
- Women representation and course guidance in science for young girls are highly questionable.

Unfortunately, the trend is not improving as, in 2022, 86% of pre-service teachers are women and only 14% studied STEM.

To remedy the problem, the Ministry of education has put up a programme called “Science plan for the primary school”. It consists of:

- Short training sessions (1-2 days typically) for in-service teachers,
- Educational support all along the school year.

The goal is to allow the teachers to catch up and gain confidence with teaching STEM. However, it is still not clear who is supposed to organise and take care of those training sessions and educational support.

We, the Liaison Committee between Teachers and Astronomers (CLEA, in French), have decided to take the opportunity to offer our help. The first reason is that promoting astronomy in education has always been the goal of CLEA since the association was founded in 1977 (for more information about CLEA, please watch my recorded presentation from the 2nd Shaw-IAU workshop). The second reason is that we are convinced that astronomy is a good way of teaching STEM, and we try to convince our local education authorities. The third and last reason is that astronomy finds itself in the French primary school curricula in the two following themes:

- “Matter on macroscopic scale, motion, and energy”, which includes observation of the sky (motion of planets and moons) and the Sun as a light and heat source.
- “Planet Earth as a place of life”, which includes locating Earth in the Solar System, habitability, Sun and planets, motions of the Earth (day and night, seasons), "direct" observations (eclipses, constellations, Venus, Jupiter), evolution of knowledge about Earth since Antiquity.

Practically, CLEA proposes short 3h-sessions on dedicated topics for up to 20 participants. Each session will consist of a $\sim$1h lecture, a $\sim$1h30 activity, and about 30 minutes of discussion. Six of those sessions are envisaged on the following themes:

- **Seasons:** axial tilt of the Earth, effect on duration of the day and solar flux.
- **Phases of the Moon and eclipses:** movements of the Moon, Sun-Earth-Moon trio, notion of a cast shadow.

- **Solar System:** geocentrism/heliocentrism, Sun and planets, properties, model of Solar System.

- **Constellations and stars:** notion of star, their colours, their distances.

- **Exoplanets and habitability:** basics of exoplanet detection, notion of habitability.

- **Astronomy and critical thinking:** critical reading of texts or images, common beliefs about astronomy.

CLEA have already developed a wealth of activities so we shall select those we want to share (no need to reinvent the wheel).

It is not clear yet how this science plan is going to work but it could be a good opportunity for us to reach out the teachers. At CLEA, we are convinced that astronomy can encourage teachers to do science in class, through multidisciplinary projects, among other things. CLEA has a long experience of astronomy education and is ready to help, even modestly. We have made propositions to national and regional education authorities.

Science Meets Storytelling in the Primary Classroom: We Share the Same Moon

Presenter: Megan Argo, University of Central Lancashire, The United Kingdom of Great Britain and Northern Ireland

Astronomy provides many avenues for teaching aspects of the primary curriculum – from science topics such as physics, biology and the climate, to maths, geography, and even art. Working with a storyteller and experienced primary teachers, we developed a set of creative teaching activities based on astronomy topics. Each activity provides background for non-science specialist teachers, a "science story", detailed instructions, uses simple materials, has cross-curriculum links, and is paired with one or more cultural folk tales which can be used to introduce the topic in a primary classroom. This contribution will illustrate the project, its resources, how we tested the activities, and show how the resources have been used in different contexts.

Poster link: https://astro4edu.org/siw/p91

We Share the Same Moon was a unique collaboration between astrophysicist Megan Argo and storyteller Cassandra Wye, with the aim of bringing together creativity and science in both formal and informal learning contexts, and of promoting cultural understanding through the use of sky lore stories from different traditions. Its aim was to help children, parents and teachers understand why science is important, using stories and creative activities. In addition to a STFC Spark Award, the project received financial support from the Arts Council England, the International Astronomical Union, and the Royal Astronomical Society.

The UK primary curriculum contains some basic astronomy as part of the science strand, and children are often fascinated by the subject and have lots of questions. For teachers without a STEM background, who may not have the confidence to answer children's questions, this can present an additional challenge when teaching these topics. If science is not taught well at primary level, this can lead to pupils being less engaged in the subject in secondary school and beyond, so support is needed to help teachers deliver science lessons in creative and engaging ways (Wellcome Trust, 2017). We Share the Same Moon was developed to help address this problem.

To celebrate the 50th anniversary of the Apollo 11 Moon landing, we developed, tested and evaluated 21 educational curriculum-linked resources linking stories and science, delivered a series of pilot workshops in schools and informal settings around the country, and produced a publicly-available website, https://www.wesharethesamemoon.org/, of fully-accessible educational resources. The science activities covered aspects of the primary science curriculum such as Earth and Space, Forces, Evolution and Light, as well as linking with several other aspects across the wider primary curriculum (e.g. geography, art, materials), enabling teachers to introduce science topics in an engaging and creative way. Each resource included background for the teacher to provide those without a strong STEM background some extra information and give them confidence in using the resources. We also collected more than 40 Moon folktales representing 19 different cultures, with each activity linked to one or more story which could be used as a gentle introduction to the topic in the classroom.

During the project we reached an in-person audience of almost 2000 people, mainly primary school children and their teachers, through testing and evaluation of our activities involving schools in deprived neighbourhoods and with high numbers of special educational needs (SEND) pupils, as well as family audiences at public events and festivals. The website has since received over 10,000 visitors and more than 35,000 page views, with the science activities alone being downloaded over 4,000 times. It remains freely available.

Resource: Wellcome Trust (2017), 'State of the Nation' report of UK primary science education, Wellcome Trust, London [online]. Available at: https://wellcome.org/sites/default/files/state-of-the-nation-report-of-uk-science-education.pdf (accessed 10/11/2022).

Stardust Hunters

Presenter: Sarah Roberts, Swansea University, The United Kingdom of Great Britain and Northern Ireland

Collaborators: Emma Wride (AstroCymru), Chris Allton (Swansea University, Oriel Science), Jana Horak (National Museum of Wales), Paul Smith (National Botanic Gardens of Wales), Rich Johnston (Swansea University), and Mark Coleman (Swansea University)

Every year, approx. 3,000 tons of cosmic dust falls to the surface of the Earth – in this contribution we present our project called 'Stardust Hunters' which aims to engage and enthuse school pupils aged 8-14 years in the relatively new research area of urban micrometeorites. The 'Stardust Hunters' pilot project enables school children in Wales to carry out searches for these tiny particles using a specially designed 'Stardust Hunter's Toolkit'. The overall aim of the 'Stardust Hunters' project is not only to involve school students with real research and help them develop their scientific research skills, but we also aim to contribute to this growing field of study.

Poster link: https://astro4edu.org/siw/p92

Every year, approx. 3,000 tons of cosmic dust falls to the surface of the Earth – in this 18-month STFC-funded pilot project, we aim to enable school children to carry out searches for these tiny particles, and using equipment in Swansea University's Advanced Imaging for Materials (AIM) facility, we will analyse these potential micrometeorites and contribute to this growing field of research. To date we have reached just under 1000 school pupils in various educational settings both in-person and online, and over 4000 members of the public via stands/talks at online and in-person events.

Aims: The Stardust Hunters project aims to:

- Provide school pupils with the opportunity to genuinely contribute to real research
- Inspire and engage school pupils
- Provide under-served communities with the opportunity to participate in real research
- Enhance the educational ambitions of young students

Materials and Methods: Schools are provided with a 'Stardust Hunters toolkit', which includes strong magnets, sorting sieves, a USB microscope, plastic bags and a sample micrometeorite (MM). Once potential MMs are found, the schools send these to Swansea University, and working with scientists and undergraduate projects students at the AIM facility, an analysis is carried out using a Zeiss EVO LS Scanning Electron Microscope and a Zeiss Xradia Versa 520 X-ray microscope.

Results: We have reached 9 Primary schools, 6 secondary schools, 1 pupil referral unit, 1 hearing and speech impediment unit, 1 learning pathways centre, 12 online schools workshops, 5 online talks to general public/educators, and 3 in-person workshops to general public (incl. 2 science festivals).

Future Work: We are currently in the process of analysing the potential MMs collected at our workshops and results are expected in the next few months. The overall aim of the 'Stardust Hunters' project is not only to involve school students with real research and help them develop their scientific research skills, but also to contribute to this growing field of study. If you would like to collaborate or give feedback, please contact the author.

Summary of Community Cosmos Workshop Project

Presenter: William H. Waller and Denise Wright, US-NAEC, Endicott College, Rockport Public Schools, USA

We report on our IAU-OAE Teacher Training Pilot (TTP) workshop for K-8 educators. Sited at Halibut Point State Park (HPSP) in Rockport, Massachusetts, USA, this one-day workshop introduces the teachers to the following astronomical topics: Exploring Earth from Earth, where teachers consider the shape, geology, and biology of Earth; Exploring Earth from Space, where teachers use Google Earth and other visualisation tools; Exploring Space from Earth, where teachers use star wheels along with desktop and smartphone apps to navigate the day and night sky. Direct and remote telescopic observing culminate this component; Exploring Space from Space, where teachers imagine and design robotic spacecraft that could enable them to explore specific worlds in our Solar System.

Poster link: https://astro4edu.org/siw/p93

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Let us begin with a question: "How can we get teachers to incorporate Earth & Space Explorations as part of their standard curricula?". One way is to get them out of the classroom and into more natural settings that are rich with Earth & space educational resources. That is what we did recently with a teacher training pilot workshop called **Community Cosmos**.

In this one-day program, we hosted elementary and middle-school educators at Halibut Point State Park in Rockport, Massachusetts – where Earth, ocean, air, and space processes converge in unique and enriching ways. By making use of the park's recently refurbished Visitor's Center as well as its fascinating natural environs, we introduced educators to exploring:
- *Earth from Earth* (mapping, discerning shape, size, geology, and biology),
- *Earth from Space* (using Google Earth and ISS Above),
- *Space from Earth* (using star wheels, planetarium software, smartphone apps, and remotely-controlled telescopes), and
- *Space from Space* (designing robotic spacecraft to sense diverse worlds).

Visitor's Center at Halibut Point State Park and the view from the tower of the Visitor's Center

Further information is provided in our poster titled "Community Cosmos: A Park-based Forum for Empowering Educators in Astronomical Exploration".

Astronomy Teaching in Primary Schools: Underrated Pupils

Presenter: Shao Faxian, Chongqing Academy of Education Science, China

We believe that the global science curriculum standards for astronomy education underestimate the actual ability of pupils. We conducted interviews with 54 students from grades 1 to 6 about the moon phase concept. It revealed that few students are working from naive mental models, and most can put forward their own guesses and carry out simulation experiments to verify. Students in grades 5-6 can even use the balls of different sizes and flashlights provided by the teacher to deduce the reason for the moon phase and refine their mental models of the Sun-Earth-Moon system. We have successfully helped grade 3 students establish the concept of the moon phase change law and the distance between the Sun-Earth-Moon by combining the embodied cognition with concrete models and mathematical reasoning.

Poster link: https://astro4edu.org/siw/p94

The teaching and learning difficulties peculiar to astronomy education make the science curriculum standards of most countries and regions continuously reduce the depth of astronomy. They mainly study factual knowledge and seldom discuss causal explanations or mechanisms. For example, as for the study of lunar phase, the Korean science curriculum clearly puts forward that the focus is to observe and confirm the periodic changes of the shape and position of the moon, regardless of the causes of the lunar phase. Some countries and regions even fail to incorporate astronomy into the primary school science curriculum standards (e.g. Finland and Singapore). China's science curriculum standard has raised the number of years of study related to the content, reducing the depth of astronomy teaching. Such settings and adjustments may underestimate the ability of primary school students to learn astronomy.

In order to assess whether the curriculum standards underestimate the students' learning ability and make clear how the pupils understand the changes in the moon phase, We conducted problem-solving interviews with 54 students from grades 1 to 6 in Chinese Mainland about the moon phase concept that most people find difficult both to understand and explain (Lelliott & rollnick, 2010).

Results:

1. Pupils basically know that the shape of the moon will change;

2. Pupils' understanding of the law and cycle of the moon phase changes increased with the grade;

3. Grade 1-2 students are prone to work from naive mental models, such as the moon becomes smaller when moon thirsty, and the moon gets smaller when it takes off its clothes; The most common explanation for the phase change is that it is covered by tall buildings, clouds, and the Earth. Some pupils also think that part of the moon cannot be seen because the Earth blocks the sunlight that shines on the moon. Through physical modelling, pupils can basically rule out the guess of being blocked by objects. Grade 5-6 students were able to successfully construct an explanation model to explain that the reason for the formation of the moon phase was related to the size and its orbit around the Earth.

4. Compared with the contents in other fields of science curriculum, astronomy education can better cultivate students' modelling ability.

The study revealed that few students are working from naive mental models, and most students can put forward their own guesses and carry out simulation experiments to verify. Students in grades 5-6 can even use physical model to deduce the reason for the moon phase and refine their mental models of the Sun-Earth-Moon system. In the science class, we have successfully helped grade 3 students establish the concept of the moon phase change law and the distance between the Sun, the Earth and the Moon by combining the embodied cognition with concrete models and mathematical reasoning. As long as the method is appropriate, pupils can also carry out simple model reasoning.

An Implementation Case of Astronomy Curriculum in Elementary School

Presenter: Li Chunyu, Beijing Haidian District Tuqiang No. 2 Primary School, China

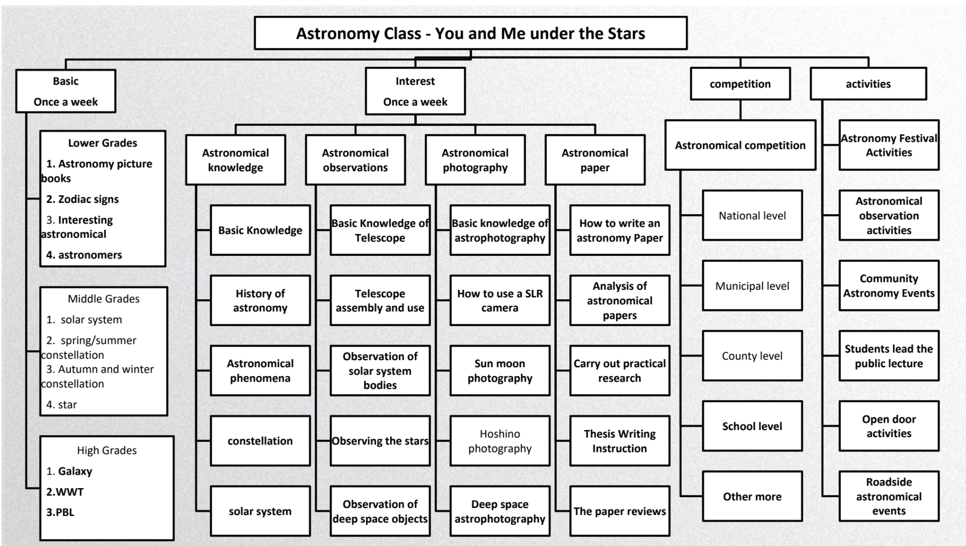
Astronomy is included in the curriculum for primary school students, and all students in grades from 1 to 6 learn basic astronomy courses. The school provides students with a variety of after-school activities, including astronomy knowledge, astronomy photography, astronomical paper writing and other interesting courses to help students develop their interests. The school organises various observation activities, photography activities and roadside astronomical communication activities for personalised and in-depth astronomy club courses for students. The Astronomy Festival is organised every year, through science and technology activities, art performances, music and other forms to carry out astronomy theme festival courses lasting for one week.

Poster link: https://astro4edu.org/siw/p95

In this contribution, I summarise how astronomy education is carried out in the Beijing Haidian District Tuqiang No. 2 Primary School.

1. Astronomy is included in the curriculum for primary school students, and all students in grades from 1 to 6 learn basic astronomy courses.

2. The school provides students with a variety of after-school activities, including astronomy knowledge, astronomy photography, astronomical paper writing and other interesting



courses to help students develop their interests.

3. Organises various observation activities, photography activities and roadside astronomical communication activities for personalised and in-depth astronomy club courses for students.

4. The Astronomy Festival is organised every year, through science and technology activities, art performances, music and other forms to carry out astronomy theme festival courses lasting for one week.

5. Organises a university-level astronomy competition with the participation of the whole school every year.

“Little Astronomers” and the Milky Way of Chinese Traditional Sky: Example Analysis of Teaching Astronomy in Primary Schools

Presenter: Liu Jing, Science and technology counselor of Guangxi Science and Technology Museum, China

This contribution takes the content of the sixth grade Chinese Distant Altair Star of the Guangxi edition of the primary school people’s education edition as an example, expounds the basic principles of developing activities with textbooks, analyses the characteristics of the development and design of such activities and the specific operation and implementation of such activities. The full text discusses and analyses how to use the methods of “role theory” and “situation creation” to turn the virtual into the real. It constructs the situation and ignites the students’ interest, stimulating exploration and promoting thinking, and emphasises hands-on exploration and personal experience.

Poster link: https://astro4edu.org/siw/p96

The galaxy occupies a very important place in Chinese culture, and there is a famous Chinese story – meet each other across the Milky Way. The Milky Way is only visible on sunny nights and is caused by the light of countless faint stars (stars). The primary school Chinese curriculum contains many scientific elements, and the Science and Technology Museum uses the characteristics of such texts to develop astronomical science education activities.

1. **Create contexts, astronomical history**
   China’s starry sky, covering ancient myths, historical allusions, social mats and humanistic

customs, is almost a reproduction of a world in the sky according to the pattern of the Earth on Earth. According to the text, explore the mysteries of the stars and explore the traditional culture and sing ballads.

2. **Role theory, cooperative inquiry**
   Traditional Chinese horoscopes are the reflection and epitome of ancient society and culture, and the most typical and vivid embodiment of traditional Chinese philosophical thought "the unity of heaven and man", which uses stories to string together the history of human exploration of the sky. In the starry sky story of "Altair", the ancients looked up at Altair and Vega, thought about the distance of 16 light-years between them, experienced how far this distance was, and thought about the contrast between myths and legends and the real world.

3. **Observation guide, starry sky appreciation**
   What is the Milky Way? Why is the Milky Way a loop? On a summer night, look up at the starry sky which has a large triangular sign as the main line, swimming in the sea of stars in the fusion of space and time.

4. **Sharing and exchange, astronomical expansion**
   Human beings really understand the scientific structure of the galaxy in only a few dozen times, and the Chinese ancients limited by history, could only make reasoning and associations, enjoying a high status in the minds of the ancients. Legends and historical allusions are all scientific and humanistic. Observe the starry sky at night and write down the results of your observations. Know the history can reach the present, let us travel through history, and reveal the astronomical culture and astronomical mysteries of Chinese national characteristics.

Construction of the Mobile Planetarium Cosmodom

Presenter: Gilbert Sánchez and Oscar Alvarado, Science and Technology Museum Mirador de la Ciencia, Venezuela

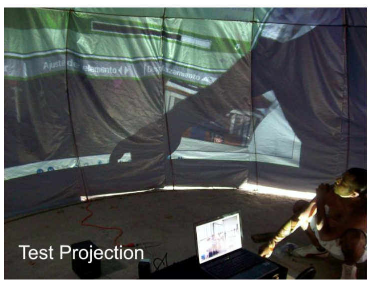
Our main objective was to design a low-cost planetarium with local resources that would allow its easy mobilisation and which will be integrated into a three-phase educational project called astronomy in the classroom, which consists of a phase of stimulation and awareness of the participants, a second pass of playful experience through the observation and visit of the planetarium and the third to capture the knowledge learned through exhibitions and practical activities.

Poster link: https://astro4edu.org/siw/p97

Every dream begins with a longing and this is the case of the first Planetarium in Barquisimeto, capital of the state of Lara - Venezuela. This planetarium with great economic, technical and operational efforts has undoubtedly become an informative tool for the Larense society, especially for children and young people. But how was the idea born? In Venezuela there was no commercial house that offered planetariums and the offers at the international level were extremely expensive, not having the economic resources to acquire it. Given these circumstances, I decided to carry out an investigative work to find a way to replicate in some way the necessary foundations to achieve its construction, see which design was the most suitable, the local materials that could be obtained, the projection method and the construction site.

To achieve the objective, together with Mr. Oscar Alvarado who, with his experience in mechanics and having a place with adequate space and tools, we began the construction of the Cosmodom planetarium. We decided after several tests with different materials to build it with our own exoskeleton design that would allow us to keep the structure suspended, unlike the classic inflatable planetariums. For the coating we use black out fabric that is used in clinics or health centers for windows and that has two layers and is waterproof. We designed an "orange slice" type mold to give it a spherical shape. The inflation system was made by adapting an air


Test Projection


Test Projection


Planetarium completed

conditioning turbine and a washing machine motor that allowed enough power to inflate the structure.

Even for the assembly and disassembly of the planetarium we devised a hydraulic method that takes advantage of the inflation force. Finally, we solved the projection system with a truck rear-view mirror adapted in distance with a DLP multimedia projector that gave us a 160-degree projected image of acceptable quality.

Astronomy Education in Primary Schools: Characteristic, Discrepancy, and Implementation

Speaker: Jin Zhu, Beijing Planetarium, China

Astronomy is a very important but quite different subject for school education, because of the characteristic of astronomy with the vast scale of universe. The frequently-appeared new discoveries and astronomical phenomena with grand observability make astronomy the most suitable tool to keep and improve the curiosity (and even integrity) of students. A text book on astronomy course in schools would be different with other subjects like language, art, math, and physics. Some special considerations for astronomy education in primary school should be noted.

Talk link: https://astro4edu.org/siw/p98

Although astronomy is one of the fundamental subject of natural sciences together with mathematics, physics, chemistry, geology, and biology, it is rarely implemented in the normal curriculum of the current educational system of primary and middle schools like other subjects. The explanation for this inexplicable situation must be closely related with the characteristic of astronomy itself. The emphasis of school education could be accumulation of well-known knowledge and development of different capacities, with obvious purpose of direct benefit of students and societies for a better future on the Earth.

Astronomy is not like other subjects, which concern mainly the human and/or the Earth. The essential interest of astronomy is of that far beyond the Earth with no direct connection with people. Considering the broadest scope of the universe and the extremely complex physical conditions which are impossible to achieve in labs on Earth, it is understandable that much more new discoveries appear more frequently which sometimes exceed our imagination in the field of astronomy. Such feature makes astronomy a science more closely related with observation, where an astronomer is in a objective position to watch and try to understand and find out how the universe operates under the physical laws, which is quite different with other subjects where scientists involve deeply with objective actions (e.g., changing experimental conditions with adjusting different test parameters) in the labs on Earth. Astronomical phenomena such as solar and lunar eclipses, meteor showers, conjunction of planets and the Moon, etc. could be easily observed with naked eyes usually in a very large area under clear skies, which is different from events in other fields where we can only learn from media without in-person experience. The usually unreachable long distance of the objects and phenomena for astronomy also make it a really simple and concise topics without additional complex consideration like possible benefits or ethical issue. This makes astronomy a suitable tools for keeping and improving the curiosity (and even integrity) of students.

However, such characteristic of astronomy would also raise some specific considerations for astronomy education, especially for the case of primary school students. Many observations involve night time and field activities, which should be performed safely with extra security considerations by both students and teachers or parents. The environment of free expression of opinions during astronomy activities may more or less conflict with the tradition of obeying the orders from authorities for kids from some cultures.

As the basic elements of scientific qualities from my personal opinion, curiosity and integrity are not only needed for the fundamental science researchers, but also necessary for everyone for a higher happiness index. Astronomy education might be the simplest way to help make the situation better in some places, but it must be performed together with all other necessary subjects and with some balances for the time of initiation and contents. Different from the textbooks mostly with absolutely correct contents in other fields, the most interested aspect of astronomy is no doubt the rapidly emergent new discoveries (which are not presented in any textbook and may still be under discussion) and the astronomical phenomena yet to be observed (with uncertain results to be determined) next week or next month. So the content of astronomy education should be different from year to year. A textbook in the traditional sense may not be suitable for the case of astronomy. Based on our practise of astronomy education for 20 years in China, we are investigating the possibility to promote such content for astronomy education via a monthly journal of astronomy outreach.

Representations of Astronomy in Children's Storybooks

Presenter: Alison Allen, Rockman et al. Cooperative, USA

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

Storybooks are widely used in schools as an entry point into science learning. As a result, storybooks should provide an accurate and equitable representation of science and scientists. Therefore, we conducted a content analysis of 32 astronomy storybooks published between 2001-2021. While about half the books include characters using at least one science practice, few portrayed characters investigating an astronomical phenomenon. Half the books contained inaccuracies. Gender representation was relatively balanced. The sample includes a relatively even distribution of characters' racial background; yet, this balance disappeared when books from Diverse Book Finder were removed from the sample. Our study suggests that there are limitations in how current children's books represent astronomy.

Poster link: https://astro4edu.org/siw/p119

Storybooks are widely used with early elementary learners at home, in school, and in informal learning environments, such as museums and libraries, as an entry point into science learning and discovery. The Next Generation Science Standards (NGSS[1]) proposes that children learn content integrated with science practices, therefore, this should be reflected in children's storybooks if these books are to provide accurate representation of how scientists do science and are being used as tools for educators when preparing students for more than factual knowledge of science through textbooks. Storybooks allow children to engage in scientific discovery, career exploration, and gain a better understanding of natural phenomenon in the world around them; therefore we sought to understand the landscape of astronomy-based storybooks.

To do this, we conducted a content analysis of astronomy storybooks for early elementary learners. We started our search using notable book lists such as WorldCat, American Library Association, and Diverse Book Finder (DBF). We filtered for books published between 2001-2021, narratives and biographies, reading levels for 3–8 year-olds, and astronomy content that excluded blackholes, astronauts, and space travel. This resulted in the analysis of 32 astronomy storybooks. A codebook was created to include how the storybooks portrayed the NGSS framework for the eight science practices; scientific accuracy of text and illustrations; engagement in scientific investigations; characteristics of the main character(s) (i.e., human/animal, gender, age, & race); and whether the author or illustrator used their own voice (i.e., term coined by Corinne Duyvis to describe books featuring characters from underrepresented and/or marginalised groups in which the author shares the same identity).

[1]NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Fourteen storybooks included at least one science practice, with “asking questions” as the most frequently found practice. Of the 32 selected books, 23 were coded as having accurate text, 3 with partially accurate, and 6 books where the premise did not portray accurate science throughout the narrative. Seventeen storybooks had accurate illustrations throughout, 10 were partially accurate, and 5 were deemed to be not scientifically accurate. Only a few of the selected books portrayed characters engaged in scientific investigating of an astronomical phenomenon throughout the entire narrative (3) or included characters investigating scientific phenomenon as part of the narrative (4). Most storybooks in the selection presented a phenomenon without an investigation (10) or delivered a collection of astronomy facts (12). Humans were the most common main characters (23). There were slightly more female characters (16) than male (13), with an additional 5 characters where the gender could not be identified by context clues. The storybook characters were primarily children (25). When the selection of books from DBF (10) was included, the racial background of human main characters was close to even between white (9) and Persons of Colour (POC) (13). However, without the DBF portion of the sample, the selection was less diverse (9 white to 6 POC).

While we were interested in investigating the extent to which astronomy storybooks align to the goals of NGSS, and to what extent storybook have a diverse set of characters to which students can relate and see themselves as scientists, there were limitations to our storybook sampling and analysis. We continue to be interested in how teachers can leverage storybooks to create hands-on, scientifically accurate, investigations where students engage in and investigate with natural phenomena.

Discussion summary

The session focused on teaching Astronomy in Primary school (pupils up to 12 years old). Different contributors discussed the importance of direct observation of the sky at this school level as a tool of the construction of knowledge. Through the description of relevant activities carried on in Italy, we started an interesting discussion about the meaning and the possibilities opened by the learning that builds knowledge from experience, not only in terms of literacy but also as profound engagement with science and its mechanisms. Obviously, this reflection cannot be detached from the one related to the teachers' and educators' educational design requirements needed to achieve those important results. Scientific analysis has been carried out in some interesting case studies, and bibliographical datasets should be taken into account.

From different scholastic systems and general conditions, we reviewed some of the best practices to open up to children a scientific point of view about the natural world: in particular, we hosted a session dedicated to Syria, before and after the war, and a session dedicated to STEM activities in Hong Kong. These active practices should be encouraged in schools worldwide.

Eventually, we discussed the importance of developing networks of students and teachers and allowing them to reconstruct knowledge together as done in the Astronomy Day in Schools (ADiS) project organised by the sub-WG of ADiS, under the WG of Astronomy Education Research & Methods, Commission C1, IAU.

Teaching Astronomy As Its Own Subject in Secondary Schools

Session organisers: Hyunjin Shim (OAE Node Korea), Jungjoo Sohn (OAE Node Korea), Suresh Bhattarai (OAE Node Nepal), and Asmita Bhandare (OAE Heidelberg)

Session overview

In this session, we heard mostly from lecturers and teachers across different countries who are passionate about teaching "astronomy" as its own subject in secondary schools. In most countries, astronomy is not listed as an independent subject in national science curriculum standards, so teachers sometimes need to re-design the annual curriculum for their students. In addition to such a specific school-focused experience, some classroom activities were also shared. The importance of cultural integration, while designing astronomy resources and activities was highlighted. Last but not least, efforts to communicate with decision makers to emphasise the importance of astronomy in its own subject was discussed.

Astronomy as a Beacon for Inclusive and Innovative Classrooms

Speaker: Rosa Doran, NUCLIO, NAEC Portugal

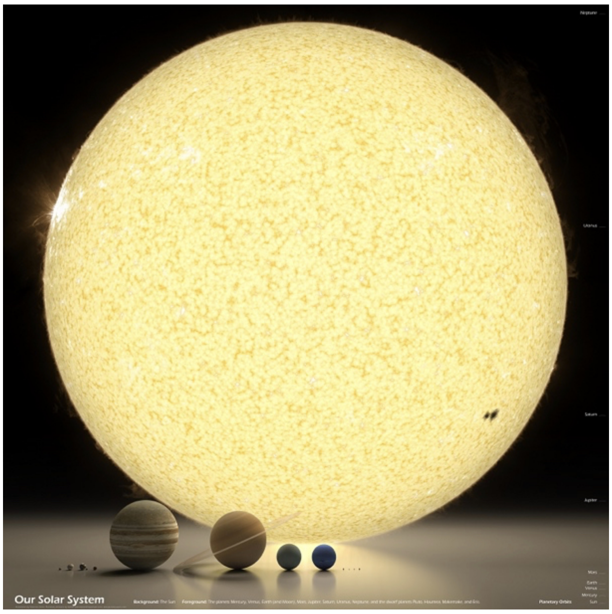
In this contribution I will summarise my ideas about how I believe that astronomy can be a beacon for inclusive and innovative classrooms.

Talk link: https://youtu.be/9cUkmjAPFd0

This contribution includes what in my mind is one of the key missing aspects in humans' education – the lack of perspective of our place in the cosmos. The importance on how information is conveyed to students and how important it is to ensure that knowledge presented is unbiased, without flavours of colonisation, or in better words, ensuring a proper localisation of the information being transmitted to the younger generation.

It is often said that one image is worth a thousand words. Well, the presentation of the Solar System in text books, in animations and even in messages prepared by space agencies could not be a better example. Due to the difficulty of presenting the main bodies of the Solar System in the same image, frequently, scales are completely ignored and information that this is the case is almost always missing. It is my belief that this is one of the reasons for a complete lack of sense of scales in the Universe and how small we are in this gigantic cosmos surrounding us. This lack of awareness might as well be the cause for a general lack of humility of beings that do not know their place and importance in the vast place we inhabit.

When it is mentioned in the media that there is no Planet B, there is always a distressing feeling that humans have no idea of what that means. How many people know that we live in the habitable zone of our Solar System? That in turn lives in the habitable zone of the Milky Way, our galaxy? How many humans know that the Milky Way is just one of the galaxies of the Local Group? And that this is just a small fraction of the galaxies of the Virgo Cluster, one of the Clusters of the Laniakea Supercluster, which in turn is a small fraction of the observable Universe?.



A part of my contribution is devoted to the importance of science literacy and critical thinking to better prepare younger generations. Astronomy is by nature inter-multi-disciplinary. It can be used to introduce any topic and provides degrees of freedom for innovation and a holistic approach to education.

I highlight the importance of changing the way schools organise the facilitation of learning. Students need to find in schools a highway to their future where innovation is invading their learning experience. More than content knowledge, students should have their competence profile enriched, they have to be prepared for a future that is not yet written. If this future is to be designed with strength and beauty, it is of utmost importance to invest in preparing teachers, they are the ones that will facilitate the journey for the students for a brighter future. They are the facilitators of a winning generation.

All efforts should be put in place to empower educators to embrace technology and adapt it to their student's needs, to be capable of choosing the best methodology to trigger the hidden talents of learners.

Finally, it is very important that educators in general apply a fair, non-obstructive and inclusive approach in their classrooms. Inclusion is a big word, and implies paying attention to the needs of each individual. Inclusion is not only something for children with disabilities, it also means embracing diversity, minorities, cultural and social differences, etc. Inclusion means embracing every individual as a unique person and allowing a differentiated path to each of them with a personalised trigger to boost their talent and foster their dreams.

I urge everyone to collaborate and join hands for the mission ahead. Thousands, if not millions of teachers need our help and we should be united in a mission to reach them all. Hope to see you all somewhere around the globe, together enriching and empowering educators.

Implementing Astronomy As Its Own Subject for Guatemalan Secondary Level Students

Speaker: Melissa Solares, American School of Guatemala, Guatemala

In Guatemala, like many other countries, astronomy is taught only as part of other school subjects like science at the primary level and physics at the secondary level. This contribution is about my experience in developing a program for teaching astronomy as its own subject in secondary school and introducing it successfully in two Guatemalan private schools. We will discuss previous research done as a way of showing the administration the importance of teaching astronomy to young students. Four years after starting this project, we can share the challenges and successful practices found along the way.

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

This contribution details how the first astronomy course as its own subject was introduced in two private schools in Guatemala. It outlines the process on how the program was designed based on the study of astronomy curriculum in other Latin American countries, how it was approved by the administration teams and the experience teaching astronomy for the first time to students during the virtual and hybrid education periods.

Astronomy education in Guatemala: Guatemala does not have astronomy as an official subject in its curriculum. Astronomy topics are included as part of the national curriculum for mandatory science courses taught during the primary education stage (ages 7 through 13), focusing on the Sun-Earth-Moon system, lunar phases, eclipses, the Solar System and cosmological theories like the Big Bang Theory and the Mayan theories for the origin of the universe.

Astronomy program proposal for high school students: To develop the curriculum, a state of the art program was carried out as an initial research stage on the contents and standards for astronomy secondary level courses around multiple Latin American countries that teach it as its own subject: like Chile or Uruguay. The information obtained was used as a starting point and adapted to the Guatemalan context. The result is the final version of the program that consists of five content units with the following standards:

1. Introduction: constellations and observational astronomy.
   Students locate the position of objects in the sky during the day and night in their daily lives.

2. A Brief history of the Universe: from the Big Bang to the Modern Era.
   Students relate the evidence of the evolution of the universe to their microscopic and macroscopic context.

Grade 11 and 12 students using telescopes in the 2021 astronomy cohort

Grade 11 and 12 students playing board games they created about stellar evolution.

3. The Earth, the Moon and their motions.
   Students predict changes in celestial bodies' appearance based on their geographical position and the current date.

4. The Solar System.
   Students recognise the unique environmental and astronomical characteristics of the Earth in comparison to other planets in the Solar System.

5. Interstellar Space, Stars, Galaxies and Nebulae.
   Students relate astronomical observations and available data to the study of interstellar events.

When the program was launched, in 2018, the school gave no budget to the class and students worked with material they brought from home. After three years of experience and student feedback, when it was proposed at a different school, in 2021, there was a part of the budget from the science department authorised for the class.

Phenomenological research: Students want to learn astronomy!
To collect evidence on why it is important to include astronomy as its own subject, there was a phenomenological research carried out in which talks were given to high school students about different topics from math, physics and astronomy and their perspective was observed and

analysed. Focus groups were carried out afterwards and students gave out comments like:
- I have always liked astronomy because it is something we can discover/explore ourselves.
- They should teach astronomy since we are little, it should be a class that everybody has to take.

This research was later shown to the administration once the proposal was ready to be implemented, and it is one of the reasons why it was approved as a formal course.

Astronomy education in practice: The successful practices described correspond to working with high school students in their junior or senior year – last two years before college education – who chose astronomy as one of their elective courses. Their report cards include astronomy as its own subject. Students from this school are constantly surrounded by technology devices such as laptops, tablets and cellphones. And the use of their devices is encouraged as part of the school climate.

Digital tools include Stellarium, Zooniverse, Star in a Box and Edpuzzle. Social media was found as a powerful tool for scientific outreach; students respond positively and advance their knowledge with ease through platforms like TikTok or Instagram. Some of the projects that students have worked on include: TikToks that show the Solar System to scale; models, role-playing or comic books for learning about constellations; and board games about stellar evolution.

The creativity shown by young adults is impressive, especially if it involves creating digital content. Hands-on activities also motivate and engage them, disconnecting from devices and doing arts and craft type projects is refreshing for them.

Recommendations: Start by taking examples from astronomy curricula in a similar context. Administration listens to students and families: if you have their support via surveys or focus groups, there are more chances the course will be approved. Have your program proposal ready as soon as possible, so you are ready when the administration approves it. Have fun with it, take new ideas, listen to students and be flexible on how they will advance their knowledge and skills.

Finding Space for Observational Astronomy in the Science Curriculum

Speaker: Gerri Bernard, Brisbane Girls Grammar School, Australia

In an effort to bring the awe and wonder of gorgeous astrophotography to all of our students, Brisbane Girls Grammar School has integrated observatory work into our Science curriculum. This contribution will explain how we use a series of 'Observatory Modules' in Years 7-9 to teach our students about the universe, telescopes, light, colour, CCD imaging, and image processing as we help them to generate more than 300 astrophotography images every year. The contribution will also include an introduction to our school's remote and robotic telescope facility (the Dorothy Hill Observatory), an outline of struggles that we have encountered along the way, and a plan for future outreach and development of our observational astronomy program.

Talk link: https://youtu.be/G-8nYkD2ixo

Astronomy has long been studied as part of the Brisbane Girls Grammar School (BGGS) Science curriculum and is currently aligned with the Science Understanding strand of the Australian Curriculum.

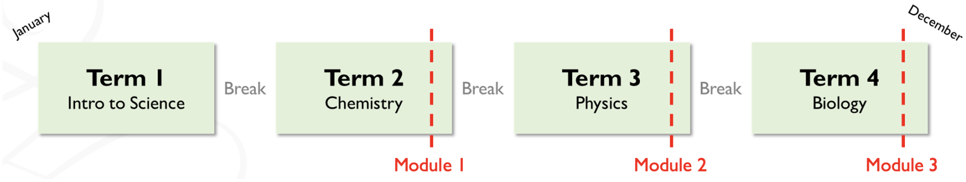
The Dorothy Hill Observatory (DHO) enhances the School's commitment to astronomy, equipping Grammar girls with the knowledge and skills required to effectively undertake research using their own primary data – rather than relying on secondary data – and publish their research to support professional astronomical projects [1].

Every student at BGGS uses the DHO as part of their Science curriculum in Years 7, 8, and 9. This observational astronomy program is delivered as nine 'Observatory Modules', which are presented by our classroom teachers and taught over the course of approximately three 65-minute lessons. These modules are progressive and increase in complexity from Year 7 to Year 9.

Due to the constraints of the Australian National Curriculum and our School's Science program, Observatory Modules are delivered at the end of one of our four yearly terms, in those lessons that occur after formal assessment is complete, but before the students leave for their term break. This method of implementation allows us to devote almost three weeks of science lessons per year to observational astronomy in Years 7-9 and results in the production of more than 400 astrophotography images per year from our students.

Year 7 students learn about the nature of our universe and the objects in it, with specific focus on deep sky objects such as nebulas, star clusters and galaxies. They are introduced to the functionality of the various telescopes in the Dorothy Hill Observatory and taught how the CCD

Year	Module	Conceptual Content	Practical Content
7	Module 1:What's out there?	Nebulas, Star Clusters and Galaxies	Request Image from Refractor
	Module 2: It's a process	CCD Imaging and Pixels	Process Colour Image from Refractor
	Module 3: Reflections	Common Issues in Astrophotography	Re-Process Colour Image from Refractor



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	Module 2: It's a process	CCD Imaging and Pixels	Process Colour Image from Refractor
	Module 3: Reflections	Common Issues in Astrophotography	Re-Process Colour Image from Refractor
8	Module 4: Going Farther	The Human Eye, How Telescopes Work	Request LRGB Image from Reflector
	Module 5: Colours of the Universe	EM Spectrum and Colour Mixing	Process LRGB Image from Reflector
	Module 6:The Universe in Motion	Dwarf Planets	Process Time Lapse of Moving Dwarf Planet/Asteroid
9	Module 7: Narrowing it Down	Emission and Spectra	Request Narrowband Image from Reflector
	Module 8: Colourful Science	Analysis of Narrowband Images	Process Narrowband Image from Reflector

telescope cameras work. Girls then choose a particular nebula, star cluster or galaxy to image using the 106 mm refracting telescope.

Year 8 students investigate how the combined functionality of the human eye and a telescope work together to produce magnified images of distant objects. They learn about the electromagnetic spectrum and the ways in which primary colours of light can be combined to make any other colour.

Girls choose a particular nebula, star cluster or galaxy to image using the 356 mm reflecting telescope, using red, green, and blue filters. They then stack and combine the images from each filter into one superior full-colour image.

Year 8 students also learn about asteroids and dwarf planets and use images from the 106 mm refracting telescope to produce a time lapse series of one of these objects moving through the sky.

Year 9 students learn about electron transition between atomic energy levels and connect this idea to the emission of light from nebulas of ionised gas. They link these concepts to atomic spectra and use this information to understand the purpose of narrowband imaging.

Girls choose a particular nebula to image using the 356 mm reflecting telescope, using Hα, OIII and SII narrowband filters. They then stack and combine the images from each filter into one superior full-colour Hubble palette image, which can be analysed to elucidate the presence and location of hydrogen, oxygen, and sulphur within the nebula.

This curriculum program is supported by co-curricular activities available to our students in all year levels. Students in Years 7-10 can participate in Astronomy Club, where they will learn about various space and introductory astronomy topics. In Years 11 and 12, students can participate in the Student-Teacher Astronomy Research Symposium (STARS), in which they can use the resources of the Dorothy Hill Observatory to complete research projects involving double stars, RR Lyrae variables, or exoplanet transits. The results of these projects are then developed into research articles for publication in peer-reviewed astronomy journals [2].

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Astronomy Education and Outreach at HUSTFZ

Speaker: Wang Qin, Huazhong University of Science and Techonology, China

The middle school attached to Huazhong University of Science and Technology (HUSTFZ) is the first characteristic middle school in astronomy education in Wu Han, China. I discuss how we got this honour and how we got our ministry to listen. I also share the syllabus of my astronomy curriculum and illustrate how we run this elective course. Finally, I focus on interactive methods for astronomy education such as physics experiments, sky observations, using information technology or physical models.

Talk link: https://youtu.be/a1_dZxigMQk

HUSTFZ was rated as the first school which features astronomy in Hubei Province in May 2021, with a validity of three years, which also urges us to actively launch astronomy courses and carry out related astronomy activities.

In July 2021, students from HUSTFZ were invited by Hunan television station to participate in the program recording of observation of China's space station. It is so rare for students to go on camera. But for the school, it is the best chance to raise our profile of featuring astronomy.

Inspired by this activity, Li Bin, a physics teacher of our school used this video to explain space navigation in class. This course was selected in the excellent course of the Ministry of Education. They also organised a meeting on astronomy education for primary and secondary school teachers in central China. In September 2021, Dr. Wang participated in the design of a science fiction film in the Science and Technology Museum of Hubei Province as a scientific consultant. Based on astronomy course, Dr. Wang won a key project of Wuhan education planning. Dr. Wang organises students to watch Tiangong classroom every time. The first time was in December. After a live broadcast that day, with another physics teacher she reproduced the ground experiments in class, such as exploring angular momentum with a rotating chair and dumbbells, and explaining the surface tension of water with paper flowers. The second one was held in March 2022. These two activities on a school level were reported by well-known local newspapers.

In 2022, her student from grade 9 took part in the Hubei astronomy Olympiad preliminary and final contest, and won the second prize. At present, Dr. Wang and several teachers are working together to compile an astronomical experiment guide book, just like the book “Astronomy Lab for Kids” by Michelle Nichols. But this book focuses on hands-on experiment with clear objectives. Every step and required background, especially related to Chinese culture, will be introduced in great detail. It is of great significance for teachers who do not have an astronomy background.

There lie some difficulties for astronomy education and outreach. Astronomy is not included in entrance examinations for high school or college in China. This implies that student will not give an importance to this subject. Teachers should have a clear picture that astronomy is just an elective course before college. The QDC is not fixed, and the class hours cannot be guaranteed. If there is an important examination, or big events, you probably will not have students in your class. Teachers have to buy everything they need for the astronomy class with their own money before they get some funding or a reward with significant honour, which is extremely difficult for a teacher in basic education system. But teachers give a higher importance to their duty more than money and the world is changing.

Project-Based Learning in the Secondary Classroom

Speaker: Shefali Mehta, Science Teacher, Princeton High School, New Jersey, USA

Project-Based Learning (PBL) has been growing in popularity in the educational setting. By introducing well-planned projects, they can serve to motivate and drive students to learn new content, collaborate in teams and be creative. However, it can be difficult to find authentic projects that capture all students' interest. This contribution introduces several projects that have been successfully implemented at the high school level that can easily be implemented into any classroom for students of all ages.

Talk link: https://youtu.be/Tntkgg6E6cQ

Project-Based Learning (PBL) can appear in many different ways in the classroom. In this contribution, we focus on PBL as a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. To make projects meaningful, there must be an authentic component to them – students must feel that they are relevant or that they can make an impact when proposing a solution. The benefits of authentic projects are many. When structured and planned well, students understand the purpose of learning and the content that we as teachers are sharing with them. They become engaged in the classroom lessons, having more interest and motivation to learn the content. Key factors to consider are student choice, expression, discussion, and reflection. Presenting the project components in advance of the content also helps to drive student curiosity and interest.

Examples from the classroom:

Top five telescopes project: In this project, students are tasked with researching and teaching the rest of the class about two telescope, one on the ground and one in space. In order to complete the project and understand how the telescopes work, they then begin learning content relevant to the project. We begin by learning about different telescopes and the optics involved in viewing far away objects. Students then learn about the properties of light and the technology used to analyse light. Once students have had time to learn about telescope mechanics, and their chosen telescopes, they share what they know about them. In small groups, students then discuss the different telescopes that have been researched, deciding on a list of the Top Five that had the highest impact on astronomy. Finally, students share and reflect on how their list compares with those compiled by other groups.

The manned vs. unmanned missions debate: Whether NASA (or other space agencies) should fund missions that are manned or unmanned can be a hot topic for students. Manned missions are great to get the public interested in space and understanding astronomy, but they are costly and have a lot of limitations due to the resources needed to support life. On the other hand, unmanned missions are much less costly, smaller, and can withstand extreme environments since they do not need to support life. This project allows students to really discuss and debate the benefits of the two types of missions. Students first choose a mission to research, then share those with the class. After learning about some of the missions, students decide if they support NASA funding more manned or unmanned missions over the next 5-10 years. They write and deliver a short 30 second speech to share their position and evidence, then take turns defending their arguments and refuting arguments made by the other side. Depending on the time available, they can also try to convince others to accept their position. An alternative to a spoken debate is to have students write a letter to the director of NASA in support of either side.

Solar system classification project: Within the solar system are so many different objects, including a star, planets, moons, asteroids, comets, etc. But even within those categories, they are not all the same. Some planets are terrestrial while others are gaseous. Some moons are cratered, others are active, and even others are captured asteroids. Within the category of asteroids, there are Trojans and Centaurs, some with rings, and even some with a moon of their own. As students learn about the different categories of objects, this project gives them an opportunity to re-imagine the classification system we use and create a new one based on more than where objects happen to be and what they orbit. They can create a new system using composition, habitability, activity, etc. to group similar objects.

Education Programs Developed by NASE and Astronomy Education Using Python

Speaker: Won-jae Sim, Won Ju Girls' High School, Korea

Python is an advanced programming language, and various libraries have been developed to use it in many fields. In the field of astronomy, libraries such as astropy have been developed and are actually used by professional astronomers. Such libraries and FITS files are open-source, i.e., anyone can use them freely. Therefore, students are able to experience the scientists' research process directly and indirectly with interest by using them. NASE has developed various astronomical education programs. Among them, there is a program named parallel earth, which explains the causes of seasonal changes, the length and direction of shadows by latitude and longitude, and the principle of day and night very accurately using only globe, toothpicks, and clay.

Talk link: https://youtu.be/9AI-oR0xqAQ

Figure 1: Teacher training using parallel earth program

The Parallel Earth program is an astronomy education program developed by Rosa. Seasonal changes and the principle of day and night occurrence are natural phenomena that can be easily understood when looking at the Earth from space. However, it is very difficult to understand these natural phenomena on Earth.

The parallel earth program has the effect of looking down at the Earth from outside of a spaceship in space. Therefore, it is easy to see the causes of seasonal changes, the causes of day and night, and the causes of different directions of shadows for each region at a glance. Rosa conducted a training program on various hands-on astronomical education programs, including the Parallel Earth program for Korean science teachers in 2020. I participated in the development of YouTube videos and educational material that introduces parallel earth programs in Korea. This activity was organised by the Korea National University of Education and Korea Astronomy & Space Science Institute.

The program was also introduced during astronomical observation training for teachers and experimental training for middle school science teachers. The parallel earth program was well received not only by elementary school teachers but also by middle and high school science teachers.

In addition, many teachers who participated in the training actively asked about parallel earth class material and necessary tools. Also, at the IAU General Assembly held in Busan in 2022, a training was conducted for teachers working in Busan. The parallel earth program has also been used in a science class. Parallel earth classes were performed with gifted students in Pyeongchang and students from Chiak High School and Wonju Girls' High School in Wonju. The students were very interested in the fact that the direction of shadows was different for each region, that they could easily understand the principles of the appearance of white nights and polar nights, and the appearance of day and night.

Python is a popular computer language. Because the structure of the language is easy and intuitive, it is used in various fields. In particular, it is used in various fields of science, and astronomers are also actively using Python in various data analysis processes. Therefore, using Python, a class on the data analysis process was conducted, which is generally difficult for students to experience. Single-session special classes using Python were conducted at Chiak High school in Wonju, Daehyeon High School in Ulsan, Seojeon high school in Jincheon and for the gifted student in Pyeongchang. During the classes, data analysis techniques using infrared

Figure 2: Astronomy class using Python

data from the Herschel space telescope and the RGB colour analysis method for continuous spectra were taught.

Python classes were also conducted in regular classes and for students' club activities. These classes lasted for a year. During this period, we performed various activities such as Hubble data analysis methods, Kepler III law, planetary orbital drawing, Voyager spacecraft's current location and solar scale, distribution of globular clusters in our galaxy, and analysis of the Andromeda galaxy, Cen A galaxy, IC434 and Barnard nebula data, and RGB color analysis of continuous spectra. After these classes, students were able to implement scientific logic courses on their own.

The classes help develop students' scientific and mathematical thinking skills and their ability to utilise a computer. Finally, they can indirectly experience the scientists' research process.

Classroom Activity to Calculate Mars’ Closest Approach to the Earth

Speaker: Lim Hosung, Gimhae Imho High School, Kyungpook National University, Korea

I introduce a classroom activity on the subject of “Mars’ closest approach to Earth”, designed for high school students. Earth and Mars are in opposition every two years and two months. When Mars is in opposition, the distance between Earth and Mars varies due to the characteristics of an elliptical orbit of the two planets. On August 27, 2003, the distance between Earth and Mars was about 55.5 million kilometres, which marked the date as one of the closest approach of Mars. With Mars’ orbital period set to 1.8808 times that of Earth, it is possible to predict the next occasion of the closest approach based on the mathematical concept of continued fractions. The activity is designed to invoke both scientific and mathematical interest in students.

Talk link: https://youtu.be/8FRfjIhjxSQ

On July 27, 2018, the distance between Earth and Mars approached about 58 million km, when Mars’ apparent magnitude was about -2.5 and looked brighter than Sirius, the brightest star in the night sky. The time when Mars is closest to Earth is the time when Mars is in opposition. The synodic period of Mars is 780 days, which means that Mars is placed in the position of opposition every two years and two months. However, since the orbit of Earth and Mars is elliptical, the distance to Mars at the time of opposition changes from time to time.

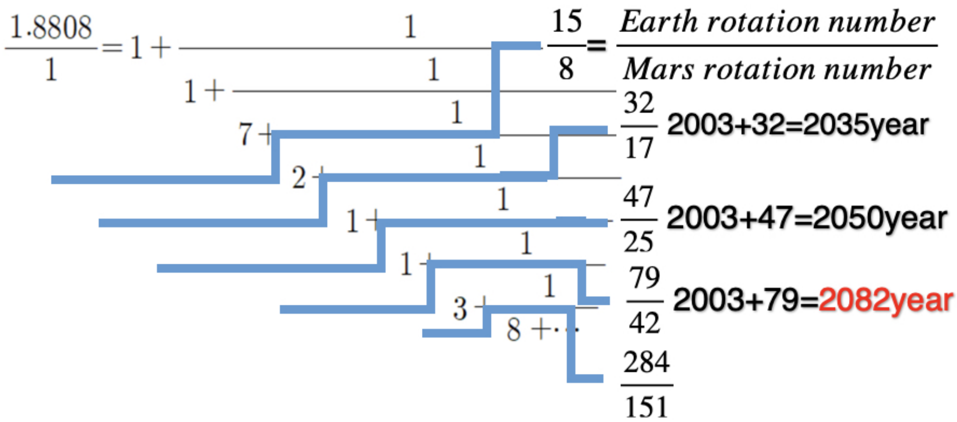
Figure 1 shows that the distance to Mars was 0.372AU on August 27, 2003. This was the closest in the recent 3000 years. Therefore the date is called “Mars’ closest approach”.

Year, Month, Day, Distance(AU)

30 July 21	0.37458	1356 Aug. 10	0.37482	2287 Aug. 28	0.37225
235 July 17	0.37436	1403 July 31	0.37362	2366 Sept. 2	0.37239
314 July 21	0.37416	1482 Aug. 3	0.37306	2413 Aug. 21	0.37422
393 July 24	0.37421	1561 Aug. 7	0.37325	2445 Sept. 5	0.37296
472 July 28	0.37434	1640 Aug. 20	0.37347	2492 Aug. 24	0.37322
598 July 20	0.37440	1687 Aug. 9	0.37434	2524 Sept. 10	0.37364
677 July 24	0.37403	1719 Aug. 25	0.37401	2571 Aug. 30	0.37238
756 July 27	0.37369	1766 Aug. 13	0.37326	2603 Sept. 15	0.37485
835 Aug. 1	0.37391	1845 Aug. 18	0.37302	2650 Sept. 3	0.37201
914 Aug. 4	0.37459	1924 Aug. 22	0.37285	2729 Sept. 8	**0.37200**
961 July 23	0.37439	2003 Aug. 27	0.37272	2776 Aug. 27	0.37436
1040 July 27	0.37382	2050 Aug. 15	0.37405	2808 Sept. 11	0.37230
1119 July 31	0.37340	2082 Aug. 30	0.37356	2855 Aug. 31	0.37311
1198 Aug. 3	0.37346	2129 Aug. 19	0.37328	2887 Sept. 16	0.37292
1277 Aug. 7	0.37409	2161 Sept. 4	0.37459	2934 Sept. 5	0.37217
1324 July 26	0.37444	2208 Aug. 24	0.37279	2966 Sept. 20	0.37404

Figure 1: Approach of Mars to less than 0.375 AU to the Earth, years 0 to 3000 (Table 36B in More Mathematical Astronomy Morsels)

How can we predict the next occasion of the Mars' closest approach? Students can use the mathematical concept of continued fractions. Continued fraction is a way to express a number as the sum of its integer part and the reciprocal of another number. Usually the numerators of a simple continued fraction are set to 1. Mars' orbital period is 1.8808 year and Earth's orbital period is 1 year. Multiplying a factor 10000 to orbital period, we get 18808 and 10000. The least common multiple of these two is 10000 times 2351. So the next closest approach will happen after 2351 years. But a human cannot live for two thousand years. So when will be the best opportunity to see at least a very bright Mars? We can calculate dates within this century when we can see the close approach of Mars.



If 1.8808 is expressed as a continued fraction, it is 15 over 8 in the third order. This means when earth orbits the Sun 15 times, Mars orbits the Sun 8 times. Therefore, the time of close approach is the year of 2018. So in this century, we can see the Mars close approach/ in 2018, 2035, 2050, and 2082. The best approximation of the Mars close approach within this century is the year of 2082.

Resource: Meeus, Jean (March 2003). "When Was Mars Last This Close?". Planetarian: 13.

A Pedagogical Activity to Teach the Seasons

Presenter: Oscar Rodrigues dos Santos, Federal Technological University of Paraná, Brazil

Collaborators: Michel Corci Batista (Federal Technological University of Paraná), Veridiane Cristina Matins (State Department of Education) and Taisy Fernandes Vieira (State Department of Education).

In elementary school, astronomy represents the gateway to the study of physics, especially in the final years. Through a simple experimental activity with the students' participation, the seasons of the year can be studied in different latitudes. It is easy to explain phenomena such as the midnight Sun, the apparent motion of the Sun, and the influence of the tilt of the Earth's axis using an experimental apparatus. Also, why the equatorial region has a more temperate climate, whereas the temperatures near the poles tend to be more severe.

Poster link: https://astro4edu.org/siw/p109

A simple experiment built by the students can be used to investigate the seasons at different latitudes. With the help of an experimental apparatus, phenomena such as the midnight Sun, the apparent motion of the Sun, and the influence of the tilt of the Earth's axis can be easily explained. In addition, the equatorial region has a warmer climate, while temperatures near the poles are more severe.

In order to contribute to the teaching of astronomy in elementary education, this work aimed at developing an auxiliary material for science and physics teachers, using simple but correct language and easy to consult, and at evaluating its pedagogical potential. The first has a quantitative approach, for which an experiment was conducted comparing the performance of elementary school students on an assessment instrument consisting of 29 questions about physics and astronomy, before and after the introduction of the interdisciplinary notebook for practical activities in astronomy. The second phase has a qualitative approach of descriptive type, for which we used a field diary prepared by the researching teacher during the implementation of the activities, as well as the documents prepared by the students as a data collection tool.

The results of the first phase were organised using the paired parametric t-test. The choice of this test accounts for the intra-individual dependence of the observations. In general, our results show a build-up of practical and dynamic thinking that motivates students to be interested in astronomy and, most importantly, a change in the attitude of the teacher-researcher in front of the classroom. Physics, geography, and mathematics are interconnected disciplines, and a practice-based approach to learning astronomy can improve their understanding.

The subject's participation and the students resuming of their role as an active person can improve their oral and written skills, and the possibility of appreciating astronomy in their daily lives. The activity, when presented to students, generates satisfaction from all. Students are positively surprised as they understand the fact that the inclination of the Earth's axis causes incidence in different ways in different parts of the surface, causing different phenomena, and the teachers are satisfied for being able to facilitate learning. We hope that this material can be used by other teachers, with minor adaptations, to provide quality astronomy content. We believe that the implemented material has a great pedagogical potential, with a motivational and reflective character.

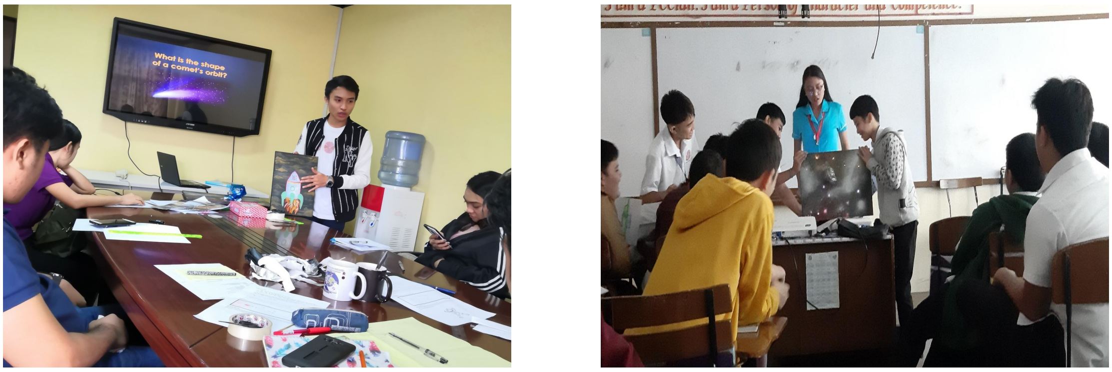
Developing Self-Constructed Visual Instructional Material for the Lesson about Comets

Presenter: Paul Anton Mahinay, Pasig Catholic College, Philippines

Education plays a vital role in the development of society. Quality education can be achieved through creative and effective instructional materials. Therefore, this study aimed to increase the achievement of learning competencies in comets through self-constructed visual instructional material. Descriptive method of research was employed wherein standardised diagnostic and achievement test was administered to 437 grade 8 students of Pasig Catholic College and the self-constructed visual instructional material was used in the discussion of the lessons.

Poster link: https://astro4edu.org/siw/p111

The K to 12 science curriculum of the Philippines provides competencies that aim for the Filipino learners to demonstrate understanding of key science concepts and application of scientific-inquiry based skills. In this curriculum, topic about comets is one of the astronomical concepts taught in secondary science. According to the DOST Science Education institute, different efforts were made to improve the science education in the Philippines and the result of their research shows the quality of teachers and learning interactions provided by the teachers affects the learning of students. In line with this, both public and private education institutions conduct



The researcher presenting his self-constructed visual instructional material.

several assessments or tests to identify the achievement of the learners, standard level of learning competencies and factors affecting the student's achievement. Thus, Pasig Catholic College together with Excelandia I.T. Services provided a standardised assessment that helped the teachers to identify the level of learning competencies achieved by the learners.

On the other hand, use of instructional materials augments the learning process of the students, making the discussion more effective (Socias 1987 & Aquino 1988). Developing instructional material is an avenue to improve the learning process especially for science concepts. Earth and space science is one of the fields of science in the K12 curriculum, and this field must be taught with visual materials, specifically the topic about comets.

To enhance the learning process of teaching comets at the secondary level, the researcher created a comet made of crumpled paper and foil. Magnets were attached to it so that it could be placed on a 18x20 canvas to manipulate it and demonstrate the movement of the comet. Fairy lights were also used to represent stars in space. A QR code generator and HP Reveal applications were also used to give additional information and to make the material more interactive.

First, the researcher painted a rocket that served as the image target and infographics about comets from google were used to create an augmented image. The researcher used HP Reveal applications for this material. On the other hand, a QR code generator was used to incorporate the story of Rosetta and Philae mission.

To check the self-constructed visual instructional material for the lesson in comets, articulation of grade 8 teachers was done, and it was used in the discussion of the lesson in grade 8 after the diagnostic test and before the achievement test administered. The researcher used a standardised diagnostic and achievement test provided by Excelandia I.T. Services. It was constructed in a way that determines and measures the standards level of learning competencies. It utilised scales namely (0%-29%) starting (30%- 59%) progressing (60%-79%) competent (80%-89%) mastering (90%-100%) outstanding.

The results show an improvement on the standards level of learning competencies of grade 8 students when it comes to the lesson of comets after the self-constructed visual instructional materials were used. It indicates that teacher preparation and creativity in the usage of self-constructed visual learning materials can help in improving the achievement of the learning competencies.

Learning Competencies in Comets	Diagnostic		Achievement	
	Correct % & standards level		Correct % & standards level	
Compare and contrast comets, meteors and asteroids	54%	Progressing	62%	Progressing
Predict the appearance of comets based on recorded data of previous appearances	17%	Starting	21%	Starting

Table 1. Grade 8 Science Diagnostic and Achievement Tests - Comparative Results

Resources:

- Bukoye, Rosaline O. (2019). Utilization of Instruction Materials as Tools for Effective Academic Performance of Students: Implications for Counselling. Department of Counselling Psychology, Niger State, Nigeria.

- Comets- Teaching Tips. Retrieved from history.amazingspace.org [Accessed December 13, 2019]

- Dauber, P. & Muller, R. (1996). The Three Big Bangs. Massachusetts, USA. Addison-Wesley Publishing Company.

- DepEd K to 12 Curriculum Guide Science (December 2013). DepEd Complex, Meralco Avenue, Pasig City

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- Dizon, M., Garcia, R., Laurente, J. & Lim, A. (2015). Science for The 21st Century Learner. Makati City: DIWA Learning Systems.

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- Volume 9 – Number 14 June 2018, pg. 129-147, Synthesis Research Journal

- Volume 39 2017, pg. 11-16, Philippine Physics Journal

Three High School Teachers Bring Subaru Telescope's Big Data to Their Classrooms

Presenter: Kumiko Usuda-Sato, Subaru Telescope, National Astronomical Observatory of Japan, USA

Collaborators: Tadashi Hara (Toyo University, Japan), Tamiki Togashi (Saitama Prefectural Kasukabe High School, Japan), Yuichiro Hiratsuka (Saitama Prefectural Yorii-Johoku High School, Japan), and Akihiko Tomita (Wakayama University, Japan).

The Subaru Telescope is a large optical-infrared telescope near the summit of Maunakea, Hawaii. The telescope conducted an extensive survey called the Hyper Suprime-Cam (HSC) Subaru Strategic Program using the ultrawide-field imaging camera HSC. The big survey data is partially open to the public, and anyone can freely explore the vast cosmic images on the hscMap website. The three high-school science teachers (Hara, Togashi, and Hiratsuka) in Japan developed educational material using hscMap to bring one of the world's highest-quality astronomical data to their classrooms, including at a University. According to a questionnaire after Hara's lecture at a teacher-training course at Toyo University, many trainee students were interested in using hscMap when they became teachers.

Poster link: https://astro4edu.org/siw/p112

The Subaru Telescope is an 8.2-meter optical-infrared telescope near the summit of Maunakea on the Island of Hawaii. The telescope conducted an extensive survey called the Hyper Suprime-Cam (HSC) Subaru Strategic Program using the ultrawide-field imaging camera HSC. The extensive survey data is partially open to the public, and anyone can freely explore the vast cosmic images on the hscMap website (http://hscmap.mtk.nao.ac.jp, http://prc.nao.ac.jp/citizen-science/hscv/index_e.html).

Since May 2021, three earth science high school teachers (Hara, Togashi, and Hiratsuka) and two astronomers (Usuda-Sato and Tomita) have had monthly online meetings and developed teaching material using hscMap. (note: Hara is a retired teacher at Saitama Prefectural Tyooka High School and now teaching at Toyo University). The three teachers shared their ideas at the online meetings, developed the prototype materials, tried them in their classrooms and/or after-school enrichment programs, and brushed them up.

As shown in Table 1, six resources were developed with different themes, duration, and levels combined with the H0 common header. The title prefix "A" means easy or moderate level, and "C" means a difficult level for calculation activities; students are required to calculate the size or distance of celestial bodies with a simple trigonometric function. Educators can tailor their teaching content by combining some of them according to the class time and students' level.

Title	Duration	Level	Calculation	Themes	Created by
H0-hscMap operation	10 - 15 min	easy	-	How to operate hscMap	Hara
A1-Hubble Classification	10 - 20 min	moderate	-	Diversity and interaction of galaxies	Hara
A2-Distant galaxies	15 - 20 min	moderate	-	Apparent size, brightness, and color (Hubble-Lemaitre law)	Hara
A3-Fuzzy objects in the Universe	40 min	easy	-	Different kinds of celestial bodies	Hiratsuka
C1-Angular distance of a galaxy	20 - 30 min	difficult	required	Estimation of the size of a galaxy and galaxy cluster	Hara
C2-Size of a galaxy cluster	20 - 30 min	difficult	required	Estimation of the ditance of a galaxy cluster	Hara
C3-Number of galaxies in the Universe	40 min	difficult	required	Estimation of the number of galaxies in the entire Universe	Togashi

Table 1: List of teaching resources

They must start from H0 to let students get used to the hscMap operation. In some resources like A2 and A3, students are required to observe the colour of celestial objects. A colour template is included in the student's worksheet to eliminate the colour difference between monitors.

The teaching material (worksheets for students and educator guidelines) listed above are available online in Japanese with free access for teachers and educators via https://drive.google.com/drive/folders/1ENAsT7T3B3Dv9wVoCUmxJkoo2di0a3I3.

A Method to Carry Out Astronomy Education Based on Curriculum Standards

Using the construction of school-based astronomy curriculum by Jiangsu Tianyi High School Astronomical Society as an example

Presenter: Xinrong Shen, Jiangsu Tianyi High School, Jiangsu Autonomous Learning Institute, Wuxi, Jiangsu, China and Zhuoyan Xie, Jiangsu Tianyi High School, Wuxi, Jiangsu, China

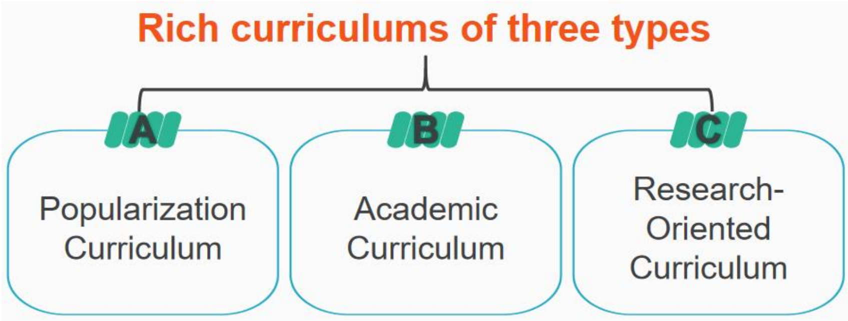
In the 2017 edition of "General Senior Middle School Geography Curriculum Standards" in mainland China, "Astronomy Fundamentals" is, for the first time, listed as an independent elective module, which lays the foundation for the development of high school astronomy education from the national curriculum standards. As a provincial-level "excellent middle school astronomical society", Tianyi Astronomical Society has systematically carried out the construction of school-based middle school astronomy curriculum based on national curriculum standards. It has developed rich curriculum of three types - popularisation, academic, and research. It has carried out a series of extraordinary research independently or in cooperation with world-leading institutions, and achieved fruitful results.

Poster link: https://astro4edu.org/siw/p113

The curriculum standard requires that students should be guided to develop a correct understanding of astronomical phenomena, stimulate their interest in exploring the universe and establish a scientific outlook for the universe by learning modules such as astronomical observation, solar system and Earth-Moon system, Sun and stellar world, Milky Way and the universe. Based on Curriculum Standards, Jiangsu Tianyi High School Astronomical Society has developed a rich curriculum of three types - popularisation, academic, and research.

1. Popularisation Curriculum: 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.

2. Academic Curriculum: 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.



3. Research-Oriented Curriculum: The prime objective is to develop research skills by using research projects in each sub-discipline and targets scientific teams and individuals.

Tianyi Astronomical Society has carried out a series of extraordinary research independently and in cooperation with world-leading institutions, and achieved fruitful results. In recent years, students have discovered 20 near-earth objects, won more than 10 medals at the International and the National Astronomy Olympiad, and won more than 100 medals at various scientific and technological competitions. students have published more than 10 papers in academic journals. A group of students entered top universities such as Peking University, Nanjing University, Princeton University, Cornell University, etc. to continue their education in astronomy.

Astronomy in Secondary Schools: Curriculum to Establishment

Presenter: Prasad Rathod, Syzygy Outreach Space Club, India

Collaborators: Vriddhi Gupta, Priyanka Lakariya, Abrar Sayyed, and Jonack Abdullah Al Mahamud.

Cognitive evolution of the brain maps our curriculum. Establishment of labs & utilisation of existing facilities is stressed. Survey of schools with/without astronomy courses forms our database. A learning model is proposed which utilises pre-existing subjects to promote astronomy. A demographic study was conducted to gather information about institutions having astronomical setups to be used as Nodal centres. To remove the fear of future uncertainty, inclusion of space startups will be done to provide internships. Research focuses on creating ecosystems within Nodal centres of under-graduates, post-graduates & PhD students pursuing astronomy to improve the syllabus and help students with their projects. MoUs schemes are devised to fulfil gaps with universities globally.

Poster link: https://astro4edu.org/siw/p114

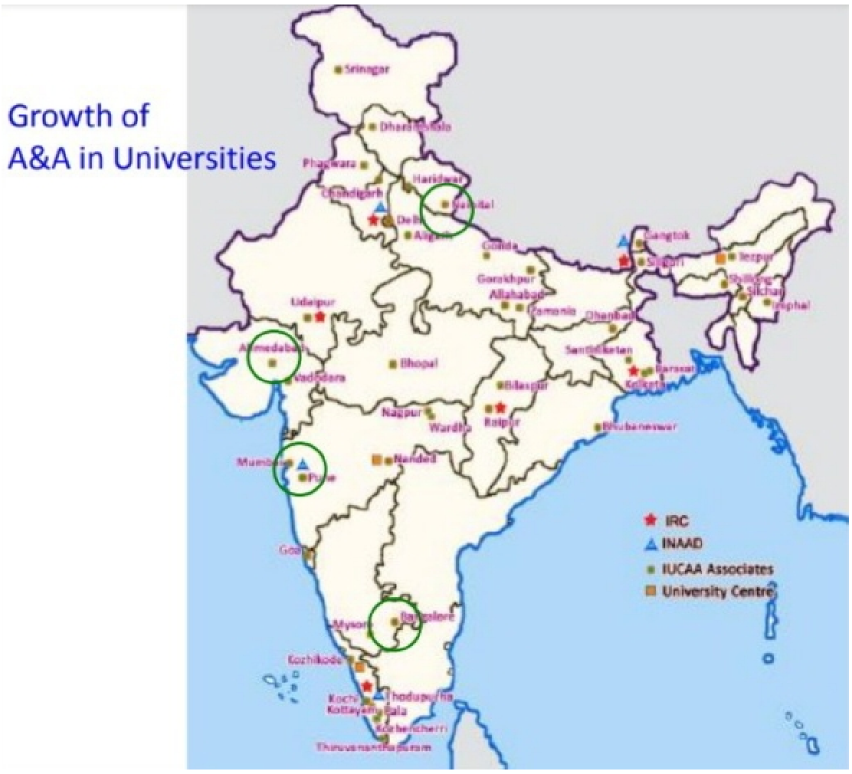


Figure 1: Demographics of Universities under Nodal Center Mapping

In our research, we study the cognitive evolution of the brain during secondary school to embark on astronomical learning. Our research focuses on development of teacher's training, developing curriculum, establishment of labs and utilisation of existing facilities.

Backed with survey of schools with/without astronomy courses, we have our own database collected for developing astronomy as a subject. Spectrum of astronomy is analysed by finding its common links with subjects such as physics, mathematics, chemistry, and geography. A tied learning model is proposed for utilising maximum support of pre-existing subjects to promote astronomy.

A demographic study was conducted, which gathered information about already existing institutions having astronomical setups. These institutions were plotted on the map of India and a density analysis was done. Research suggests use of these institutions in multiple phases to establish astronomical board of studies having them as nodal centers. These will facilitate schools by providing them instrumental assistance for cost-effectiveness. To remove the fear of job and future uncertainty plus providing application-based insights, inclusion of space startups will be done to provide meaningful opportunities to students in the form of internships.

Research is based on creation of ecosystem having under-graduates, post-graduates & PhD students pursuing astronomy in Nodal centres. They will have access to a repository of thesis/projects by these students. Projects can be displayed/tested in schools to help schools students have a better overview. Gaps in educational setup come when things revolve around infrastructure. Heavy use of physics, chemistry and other labs is incorporated in this research.

Additionally, MoUs and settlement schemes are devised in this research to fulfil gaps with universities around the world. Special focus on monetisation of infrastructure is done to motivate schools to undergo economic reforms. The syllabus is designed to mostly cover important cognitive skills. Coupled learning is an additional feature where astronomy is integrated with main-stream subjects. The syllabus has an extensive goal of helping students perform well at International Olympiads and develop a scientific temper.

Implementation of syllabus is so economical that none of the schools will feel the burden at any stage because of the use of cost-effective learning tools. Implementation of the whole subject is planned in such a way that it uplifts economy and creates potential hot-spots for future expansion and growth. Phase-based approach for 7 years from start of initiation of this subject is devised for smooth introduction and establishment. Methods for assuring quality delivery of this subject have also been discussed, which include mandatory procedures to be followed by institutions. This mandatory clause also includes a portion that enables personal growth of teachers in this subject, which never lets the dynamic nature of this subject fade away.

Discussion summary

The discussion focused on curriculum development, hands-on astronomy activities and incorporating existing teaching-learning resources at elementary-school, middle-school and high-school.

Astronomy educators from across the globe shared their experiences and different cultural perspectives on working with students and teachers and highlighted different issues faced, while implementing astronomy as its own subject in their local schools. The differences in introducing astronomy education in public/government versus private schools was also pointed out.

Project-based learning (PBL) was seen to be a useful way to introduce hands-on astronomy activities. Some panellists also pointed at some existing resources such as NASE courses and the advantage of student-centric classrooms.

Participants discussed faster processes of creating different projects, especially for those astronomy educators who volunteer extra time to develop these outside of their regular jobs. The lack of trained teachers has always been a major hurdle in promoting astronomy education and hence the need and importance of teacher training programs was voiced, either in-person or as a virtual workshop.

Teaching Astronomy as Part of Other Subjects – Astronomy as a "Gateway Science"

Session organisers: Jin Zhu (OAE Center China, Nanjing), Cui Jie (OAE Center China, Nanjing) and Asmita Bhandare (OAE Heidelberg)

Session overview

Astronomy intersects with many courses, such as mathematics, physics and chemistry. It is well suited as a gateway science.

This session brought together a panel of experts with vast experience in teaching astronomy as part of other subjects for school students: Lakshmi B R (Jawaharlal Nehru Planetarium), Eleen Hammer (Friedrich-Schiller-University Jena) and Manuel Felipe Núñez Díaz (IES Alcalde Bernabe Rodríguez) shared how to teach math with astronomical examples; Qiao Cuilan (central China normal university) and Simon Christopher Reynolds (School of Physics & Astronomy, University of St. Andrews) combined astronomical experiment with physics; Xu Li (Apple Garden Middle School in Beijing) provided experience in teaching astronomy in after-school activities; Ricardo Moreno (Colegio Retamar in Madrid) introduced the construction of easy spectroscopes to observe Fraunhofer lines in the NASE courses; Robert Hollow (CSIRO) and Mila Mitra (STEM & Space India) explored how to take forward astronomy in schools; John Boisvert (Slooh), Joanna Holt (Netherlands Research School for Astronomy & Amsterdam University of Applied Sciences), and John Carlos Mora (Expoastronomy) introduced the different ways that telescopes are used in the classroom: online telescope, semi-live data from telescopes and software used to analyse astronomical images; Andrea Ettore Bernagozzi (Astronomical Observatory of the Autonomous Region of the Aosta Valley) shared their project about giving the students an opportunity to talk to researchers and experts in astronomy and other fields; Marcelo de Oliveira Souza (Universidade Estadual do Norte Fluminense and Louis Cruls Astronomy Club) introduced a project for finding young talent for astronomy via training students in physics and astronomy.

They talked about their classes and projects, allowing us to learn from their experiences when teaching astronomy in schools.

Astronomy – A Gateway to Teach Trigonometry

Speaker: Lakshmi Bekka Ramachandra, Jawaharlal Nehru Planetarium, Bengaluru, India

When students are introduced to Trigonometry as something totally new, they find it very difficult to understand. When the same topics are introduced as another way of expressing the ideas of Triangles and Circles that are already familiar to them, we as teachers will be bridging the gap between known and unknown. We will be leading them to understand the "Unknown" through "Known". Bringing in examples from astronomy greatly helps in building this bridge. In this contribution, I would like to share my experience of conducting workshops for Teachers on "Trigonometry through examples from Astronomy". This approach would be beneficial for both teachers and students.

Talk link: https://youtu.be/e-4Nhy_4e4Q

When we introduce Trigonometry to students for the first time, the first problem we and our students face is that the topic is very new. To overcome this problem, the first thing we need to do is to develop the concepts of Trigonometry as an extension of ideas that they have already learnt while studying Triangles and Circles.

Introducing Trigonometry through some real life situations and something that is very much liked by the students is one big step in taking the subject close to the students. Astronomical examples play a very important role here.

In Trigonometry, we introduce them the method of finding heights and distances. Real world examples of estimating the height of a tree using nothing more than a stick is a good one.

But extending your vision and reaching the sky will make Trigonometry very interesting. Say for example, measuring the altitude of Moon or any particular star in the sky can be done by using the concept of angular size. We use our hand as a tool to measure angular sizes.

While conveying the idea of Angular size, we can bring in our tan θ and also reinforce the ideas learnt while studying circles. Generally, when we draw diagrams to explain the angular diameter, we might use diagrams like Fig. 1 shown here.

There is something conceptually very much incorrect here. In both of these figures, we have right angled triangles. It is true that we can use 'tan of the angle' to calculate the radius or distance. On the other hand, if we know the real radius and distance, we can find out θ which is actually the angular size. But where will be the right angle formed? The mistake is actually in representing the right angle. That is where we need to reinforce the idea learnt in Circles. The tangent and the radius drawn at the point of contact have to be perpendicular to one another. So right angle of the triangle has to be that one and not at the middle as shown in Fig. 1. Figure 2 is free of that kind of a conceptual error.

Once they are introduced to the concept of measuring the angular sizes and angular separations using their hand as a tool, we can ask them to measure the angle of elevation for inner planets like Mercury and Venus. Recognising Venus will be an easy task.

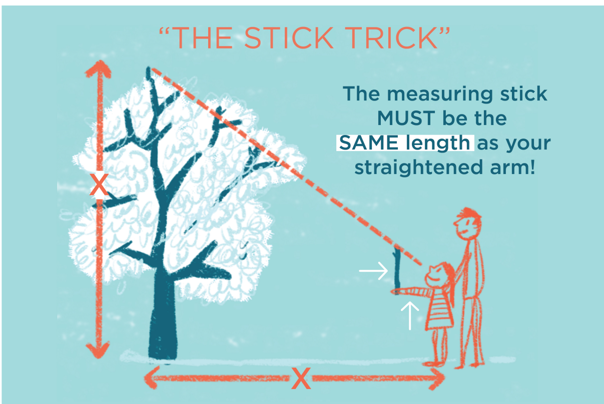
With repeated observations, they will come to know that the maximum elongation for Venus can be between 45 degrees and 47 degrees. After knowing the greatest elongation angle α, distance to Venus from Sun can be figured out just by using definition of Sin α.

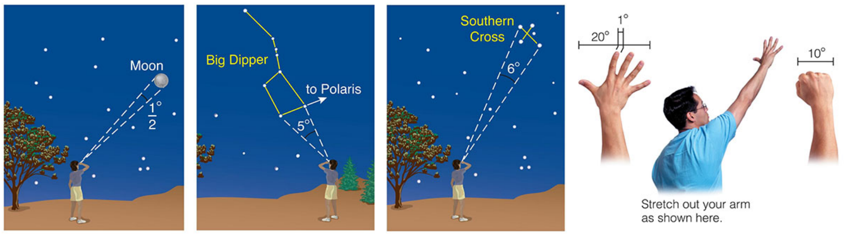
Again, we will have to stress on the concept of circles here. An interior planet cannot be seen at any elevation in the sky. Its greatest elevation can be geometrically represented by drawing a tangent to its orbit from Earth's position. Of course we are approximating the orbit to be circular here where as in reality we know it is an ellipse. Also, we will have to make them realise that angle EVS is the right angle and not the angle VSE.

If the same activity of measuring the greatest elongation of an inner planet is made over an extended period, one can actually figure out the entire orbit of the planet. The very fact that the angle of greatest elongation is not a constant but varies over a small range, conveys that 'r' is not a constant and the orbit is not a circle. The figure below shows how the orbit of Mercury can be estimated using the greatest elongation data.

In a similar way, while discussing about the angle of depression, we can introduce Albiruni's method of finding the size of the Earth. He went to the top of a mountain whose height was known to him and observed the angle of depression δ for the horizon. With simple geometry he could show that the angle formed at the centre of the Earth in the following kind of a figure will also have to be the same angle δ.

Nothing more than definition of cos δ and a little bit of further simplification was all that he needed to find the radius of the Earth as the height of the mountain was known to him.





Angular measurements with your hand as a tool.

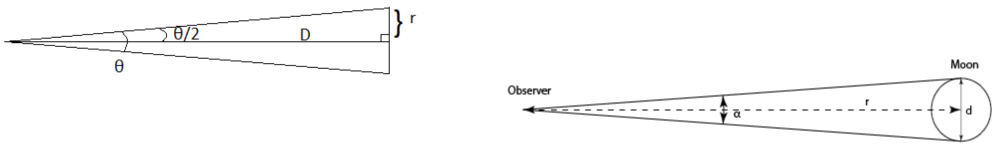


Figure 1: Diagrams to explain the angular diameter

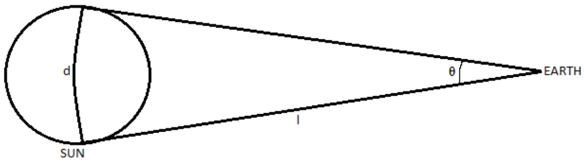
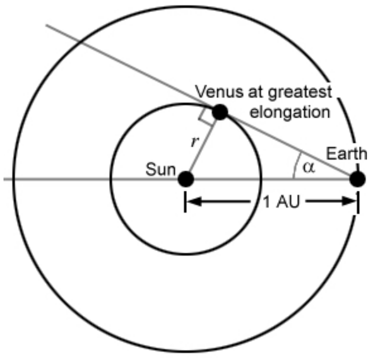
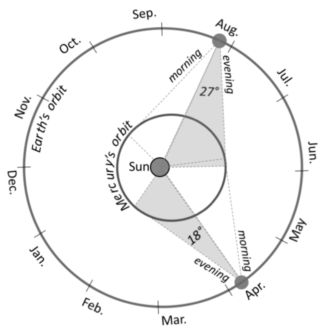


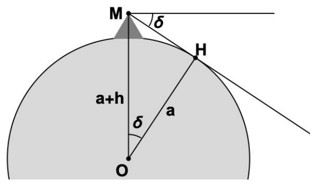
Figure 2



Greatest elongation of Venus



Orbit of Mercury by Greatest elongation data



Albiruni's method of finding the size of the Earth

Likewise, we can bring in many other examples from astronomy to teach Trigonometry. By doing that we would have helped students to get a feel that Trigonometry is not totally unknown. We can lead them from known ideas of circles and triangle towards the newly introduced concepts of Trigonometry. And concepts of astronomy can serve as a gateway to teach Trigonometry in an interesting and interactive manner.

Learning about Astronomy in Mathematics Lessons

Speaker: Eleen Hammer, Friedrich-Schiller-University Jena, Germany

Mathematics lessons do not only involve the study of different solution methods, but also the application to problems to provide purpose and benefit to the methods learned. This is where the interdisciplinary nature of astronomy can be utilised. In this talk, a project is presented in which astronomical facts and laws are transformed into mathematics problems for lower secondary school. The developed problems comply to modern competence-based mathematics lessons and convey interesting facts about our universe. It allows students to acquire some astronomical education even in cases in which astronomy is not taught as a separate subject. The problems are designed such that also a teacher with little to no astronomical knowledge feels confident in using them. Exemplary problems will be shown.

Talk link: https://youtu.be/0Pv1qGsxpGc

Astronomy has to fight for its place in the schools' schedule. The schools usually, and sadly, get only a limited number of lessons per week or none at all for the subject astronomy. In some cases, they integrate astronomy in the physics curriculum, in other cases astronomy is not even part of formal school education. Germany is no exception to this. That is why I decided to bring some astronomical content into the mathematics classroom.

Reasons for and benefits of astronomy in math lessons: In Germany only three of the 16 federal states teach astronomy as a separate subject in lower secondary school (grades 5 to 10). Which means that some students leave school without having even a basic knowledge of the universe or of the objects in the sky they daily see. Mathematics however is a mandatory subject for every grade with four to five lessons per week.

Within these lessons students are confronted with two types of math problems: the technical ones, which only require the knowledge of a solution method, and the applied problems or world problems, which depict a situation (more or less credibly from real life) that needs to be broken down. So, the applied problems have an additional topic other than math. A math textbook analysis shows what these topics are. It also shows that astronomy is the least used topic for applied math problems in the analysed book series.

By developing applied math problems with astronomy as topic, several astronomical facts and laws can be conveyed to students. It is also enriching that real data is used for the problems in contrast to the often artificial-appearing problems.

Adapting astronomical content for math problems: The astronomical content needs to be adapted to fit the mathematical content and the age and skills of the students. The general scheme that is used for the adaption process is shown in Fig. 1.

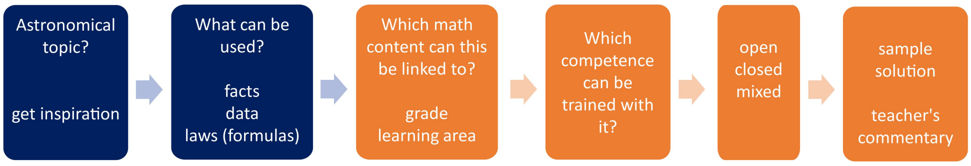


Figure 1: Scheme that is used for adapting astronomical content for math problems

Astronomy (blue boxes): Topics that you can choose for a problem can come from basic knowledge in astronomy, new research areas, or topics getting attention in the media. Once the topic is selected, you decide on whether to use a fact, a data set or an astrophysical law. If you choose a fact, you focus on conveying this one fact. If you choose a data set or an astrophysical law, it requires more explanation of the concept.

Math problems (orange boxes): After choosing a topic, you determine what mathematical content goes well together with the astronomical content. In the case that your curriculum is competence based, you need to construct competence based (sub-)problems and also decide if the problem is open (not just open-ended) or closed. When creating problems, always have in mind that the students should learn something about astronomy too.

Teachers (last box): To reduce the teacher's reservations about using astronomical problems in their lessons, you should provide a sample solution, as well as a teacher's comment. The comment explains more about the astronomical topic and, if applicable, reveals simplifications that have been made.

Examples: I will demonstrate this process with two examples of applied math problems I developed (Fig. 2). The first one teaches the students one easily understood fact: Long ago there might have been an ocean on Mars. The second example is about Hubble's Law. To understand this law, students first need to grasp the concept of expanding space, understand a new "space unit of length" and even more. Though you can approach both problems the same way with the previously shown method, in practice they will be different, since there are different preconditions. Feel free to try it out yourself in your lessons!

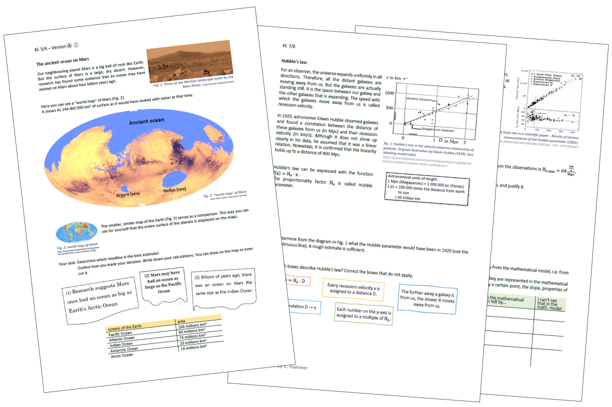


Figure 2: Two examples of the developed applied math problems with astronomy as a topic

Teaching Design and Practice of Constellation Circuit

Speaker: Cuilan Qiao, Central China Normal University, China

After studying series and parallel circuits in junior or senior high school physics, students can design and make a constellation circuit. At first, students learn about constellations, then choose a constellation and design the circuit diagram of it. Students consider series or parallel connection, and choose the colour of LEDs, resistance value of resistor, etc. After that they make the constellation circuit according to materials provided by the teacher, such as colour ring resistance, circuit board, LEDs, welding equipment. In this case, physically, students will deepen their understanding of series and parallel circuits; in astronomy, they can further understand constellations; in technology and engineering they can design and manufacture circuits.

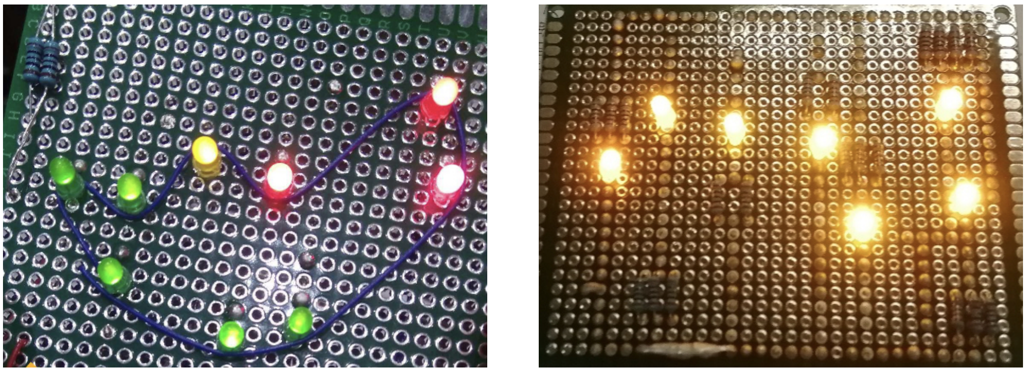
Talk link: https://youtu.be/C0xbpTaJR60

In China, usually physics, chemistry and biology are compulsory for secondary school students. Take physics for example, students usually have four physics classes each week for two or three years. While astronomy is optional for them. Only a few secondary schools offer astronomy classes, which are about one astronomy class each week for half of one year for students. The knowledge about series, parallel circuit, LEDs is important in physics for secondary school students in China. Students need to master and apply them well. So teaching astronomy as part of physics, i.e., astronomy as a "gateway science" in secondary schools is a good method.

Based on the background, we designed the practical activities of constellation circuits for students in secondary schools. The task is: after studying series, parallel circuits, LEDs etc. in junior or senior high school physics, students can design and make a constellation circuit. The first step is that students review circuit knowledge, and learn about constellations. Then they choose a constellation and design the circuit diagram of it. Next, students consider series or parallel connection, and choose the colour of LEDs, value of resistor, etc. After that they make the constellation circuit using the material provided by the teacher, such as colour ring resistance, circuit board, LEDs, welding equipment.

Teachers who are working in secondary schools often take part in some national and provincial training projects in China. We put this case into practice based on a national training program for secondary school physics teachers in Wuhan city, Hubei province. Different from secondary school students, teachers are more familiar with the knowledge of series and parallel circuits. Therefore, in principle, their practice is less difficult than that of secondary school students. Even so, we still encountered some unexpected challenges, which made it difficult for us to apply the theory in practice.

The first challenge was the question of using either series circuit or parallel circuit. It seemed that both circuits meet the needs, but after considering the volume of batteries and the maintenance



The circuit of the Big Dipper and Capricorn constellation made by teachers

of circuits and encountering some problems at later stages the parallel circuit turned out to be a better choice than the series circuit. At the beginning of the practice, I guided them to learn about constellations, including the name, colour, brightness, distance of constellations. And then teachers further studied constellations using the Worldwide Telescope. After that the teachers worked with groups, and selected one of the 88 constellations to design the circuit. More teachers chose series circuits at first. After discussing together, they reached an agreement to design a parallel constellation circuit.

The second challenge was connected to LEDs and resistors. Although the teachers were familiar with the unilateral conductivity of LEDs, they did not have a clear concept on LEDs' resistance value. In addition, they did not know how to read the value of colour ring resistances usually used in engineering. After learning the relevant knowledge, teachers successfully passed the challenge and learnt more about LEDs and colour ring resistances.

The third challenge was welding. Most of the physics teachers in this training are very good at teaching, but quite a few of them are not good at welding and are not familiar with the circuit boards commonly used in projects. After trying and experiencing some shortcomings, the teachers quickly grasped the tips of welding, and eventually made the constellation circuit.

On returning to their schools, some of these teachers also guided their students to make such constellation circuits, and they reported that this helped students deepen their understanding of series and parallel circuits; in astronomy, they had a better knowledge about constellations and in technology and engineering they could design and manufacture circuits.

Junior High School Astronomy to Improve Comprehensive Literacy

Speaker: Xu Li, Apple Garden Middle School Affiliated to Capital Normal University, China

As one of the after-school services, the astronomy club of Apple Garden Middle School (China) strives to create vivid and comprehensive active courses to help effectively improve students' comprehensive quality. In this contribution we share how we developed an astronomy course for our club, including designing "Earth spacecraft", "Planet Fleet", "Planet Home" and other sections. Students form a fleet of planets and stars and use books, the web, space station lessons and equipment at hand to explore points of interest and present them via a video. They can make interstellar warships and planets with 3Done and 3DoneAI softwares. Students get points to win the "Space Energy Card", in exchange for books, production and 3D printing privileges, to enhance their interest.

Talk link: https://youtu.be/cdIiAet68Kk

Constrained by the pressure of the high school entrance examination, junior high school students are prone to fall into a state of hard study, which is not conducive to the comprehensive development of students. Therefore, as one of the after-school services, the astronomy club strives to create vivid and comprehensive activity courses to help students effectively improve their comprehensive literacy. The course is based on "Earth Spaceship", "Planet Fleet", "Sky Vision", "Heavenly Zoo", "Stellar House", "Space Fireworks" and other sections. Students form planets, stars and other fleets, with the help of books, networks, astronomy science venues and special materials provided by teachers, etc., under the guidance of task lists to conduct discussions and exploration, and independently expand according to the strengths of each group, cooperate within groups, compete between groups, and get some useful results.

At the same time, combined with cutting-edge technology, social hot spots and students' inner love, guide students to carry out creative painting, story adaptation and broadcasting, creation and rehearsal of astronomical popular science dramas, etc., to deepen students' astronomical literacy. With the help of the science and technology innovation platform, they learn information technology such as modelling and programming, and carry out scientific and technological innovation production such as lunar exploration and fire detection; they use the Tiangong classroom to compare heaven and earth and deepen the integration of astronomy and disciplines.

Astronomy is gradually internalised into students' subject learning and speciality development. Junior high school students participate in the astronomy competition, drive internal growth, gather strength. Organised club activities around important celestial phenomena and festivals help nourish the hearts of teachers and students. For a quantitative evaluation, students earn points to win "space energy cards", and exchange them for books, production, 3D printing privileges, etc. at the end of the semester to enhance their interest and solidify the results.

Easy Spectroscopy in Classroom

Speaker: Ricardo Moreno, Colegio Retamar in Madrid, Spain

Collaborators: Rosa M. Ros, Beatriz García and Ederlinda Viñuales (Network for Astronomy School Education – NASE)

In the activities of the workshops of the NASE courses for teachers and professors, participants learn to build various instruments using very simple materials in order to analyse light. These activities, referring to the discovery of He in the Sun, or to the analysis of the light of the stars or the atmospheres of exoplanets, can be used in high school physics and chemistry classes. With these materials, we can observe the spectrum of Na from a candle flame doped with NaCl, the spectrum of Hg, Na and H from discharge bulbs, and finally, we teach how to see the Fraunhofer lines in high definition, without any slit or spectroscope, just with a DVD, using second-order reflection, and to distinguish the Mg triplet, the Na doublet, and hundreds of lines of Fe, H, etc. of the solar spectrum.

Talk link: https://youtu.be/3j_ed68vakA

In the workshops of the NASE courses for teachers, the attendees build with simple materials, various instruments to analyse light. With these instruments you can observe the Fraunhofer lines of the Sun, the Na spectrum of a candle flame, and the spectrum of Hg, Na and H from discharge bulbs. Those activities, which in the NASE courses refer to the composition of the Sun, the information that reaches us in starlight or to the analysis of the atmosphere of exoplanets, can be used in physics and chemistry classes of high school curriculum for students aged 15 to 18 years old, when the electronic configuration elements and emission and absorption spectra are taught.

As is known, shortly after the start of spectroscopy, Fraunhofer discovered dark lines in the spectrum of sunlight that corresponded to the gases present in the superficial layers of that star. The chemical element was named Helium, after Helios in Greek which means Sun, because it was first discovered in the Sun, before it was found on Earth.

The spectrum of starlight is fundamental in astronomy: it helps us to know the composition of nebulae and stars, its temperature and other properties, and also to measure the distance to galaxies.

Usage of a graduated spectroscope

Flame of a candle doped with NaCl

Na line (589 nm)

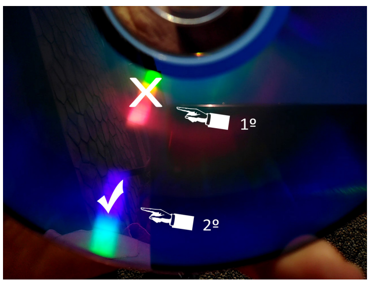
With spectroscopy today exoplanets are discovered using radial velocity, which is measured by the Doppler effect. On the other hand, if a planet with an atmosphere passes in front of star, new lines are added to the absorption spectrum that reaches us from the light of that star, and you can analyse the elements that are in the planet's atmosphere.

We propose two simple activities to see the emission and absorption spectra that can be used in the classroom when studying the electron configuration of matter.

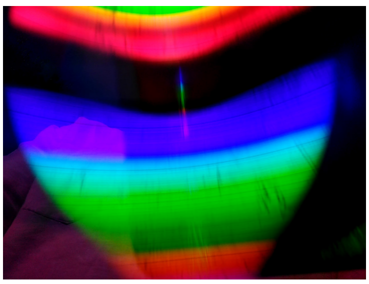
The first activity is the construction of a scaled spectroscope to measure wavelengths. It is built with a paper template, which can be downloaded from the materials section on the NASE website. The diffraction grating is obtained from a CD or DVD, by cutting a piece. For a DVD, the transparent piece is separated by bending, while for a CD, an adhesive tape is used to remove the metal part. That transparent piece is glued on the window from where the light will be observed. The numbers are hundreds of nanometers.

With this spectroscope it is possible to observe and measure the sodium line of a candle flame doped with common salt (NaCl). The light from a normal flame has a continuous spectrum. If we take some NaCl, and add a few drops of water to obtain a paste, and it is doped, it is put in the wick of the candle, looking at this flame with our spectroscope, a continuous spectrum is clearly seen, and within that spectrum, a bright yellow line is visible, which is the double line for sodium, in 589 nm.

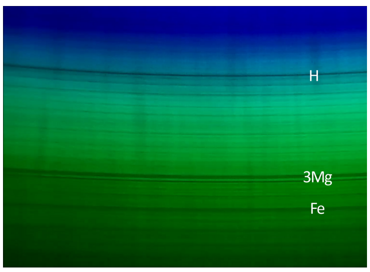
The second activity is how to observe the Fraunhofer lines with a DVD. It is not well known that due to the 1300 l/mm, Fraunhofer lines can be seen with naked eyes in the reflection of sunlight on a DVD. Among many other lines, it is easy to distinguish the Mg triplet in the green zone and the Na doublet in the yellow zone.



We use the 2nd order reflection



When we look closer, the Fraunhofer lines can be seen



You can see the lines of H, Fe, the triplet of Mg

If we stand in front of the sun with a DVD in hand, and with the reflective part facing up, we will immediately see a coloured reflection in a radial way. If we look carefully we can see that they contain two spectra: one near the center of the DVD, due to first order of reflection, and another more external, due to the second order of reflection. We use the second less bright one since it is not dangerous for the eyes.

If we get closer to that reflection it widens and we can see that it contains some very sharp black lines. Changing the position of the eye, generally a few cm from the DVD, we can cover the entire visible spectrum full of black lines of different intensity, these are the Fraunhofer lines. Many are seen, some of which are the hydrogen Balmer series.

The first-order reflex can be observed closely at sunset, when the sun rays have less intensity. Compared to the second order, it is a brighter spectrum but with the lines less separated. It is also interesting to observe that at those hours in the evening some new lines appear corresponding to the Earth's atmosphere, more noticeable as sunlight passes through thicker atmosphere.

This simple spectroscope can also be used to observe the light from street lamps that use discharge light bulbs, or fluorescent tubes, containing gases inside. For the lines to be sharp it is enough for the bulb to be several meters away and thus the light source will almost be a spot, and no slit is needed. Emission lines are remarkable. These spectra can be distinguished from those of led bulbs, which give a practically continuous spectrum.

With these activities, students can carry out a qualitative analysis of these gases in their classroom, comparing its spectrum with those of known gases found in public books or database.

Plates for Education – Scotland

Speaker: Simon Christopher Reynolds, School of Physics & Astronomy, University of St Andrews, UK

We present a project that embeds physical artefacts from astrophysics research in secondary school education in Scotland, and trains physics teachers to engage their pupils with astronomy and research data. The Sloan Digital Sky Survey has produced one of the largest maps of galaxies in our Universe, using 80cm aluminium plates to position optical fibres. After their single use, these plates have no value for research - but huge value in the classroom. Following earlier 'Plates for Education' activities in the US, we provide secondary teachers with a plate, training, classroom resources and research data. We also present a parallel education research project, assessing the impact of teacher professional learning on their well-being and physics identity.

Talk link: https://youtu.be/2sFgC9OD_f8

The Sloan Digital Sky Survey (SDSS) is a large survey of stars, galaxies and quasars. It has collected data over the last 20 years, to answer a variety of research questions. SDSS makes its observations with the 2.5m Sloan Foundation Telescope at the Apache Point Observatory in New Mexico, USA, and more recently also with the 2.5m Irénée du Pont Telescope, at the Las Campanas Observatory, in the Atacama Desert, Chile.

SDSS includes both imaging and spectra. It imaged around 1/3 of the night sky, from ultraviolet to near-infrared, and all of the imaging data are publicly available (http://skyserver.sdss.org/dr17/). The spectra of over 4 million objects have been recorded, and measuring the redshifts from galaxy and quasar spectra has created one of our biggest maps of the Universe. Recording this many spectra has only been possible using a multi-object spectrograph, to record 1000 spectra at a time. This required a system to position 1000 optical fibres at the telescope's focal plane. For SDSS this was done by plugging 1000 optical fibres by hand, into a unique plug-plate for each region of the sky, with 1000 holes positioned for the locations of individual objects. Over 10,000 such plates have been produced, and after the spectra have been recorded for the objects in that patch of sky, the plates have no further value for research.

Previous work: SDSS started distributing retired plates to educators in 2015 and plates have since been placed with teachers around the world. The 'Plates for Education' programme is ongoing in the USA. SDSS also produced a suite of educational resources, available in English and Spanish (http://voyages.sdss.org/). The activities get school pupils using SDSS research data including the imaging, spectra, coordinates, redshifts, etc. 'Plates for Education, Scotland' started in 2018 with a teacher focus group, a 'hack-day' for various stakeholders, and various pilot teacher professional learning events.

Current work: The current format of the teacher workshops includes 4 hours of contact time, in-person or online. Teachers are provided with a plate for their school to keep; an introduction by a research astronomer; training to introduce this astronomy work confidently and be able to work with SDSS data; and activities adaptable for different secondary Physics classes. We are trying to not dictate how teachers use these materials but allowing the teachers to consider how they can best adapt it to use within their own class teaching. Teachers who have already been actively using the resources in class are invited to share their experiences and give examples of how they have fitted the resources to their curriculum teaching.

As part of the training, teachers complete two activities adapted from SDSS Voyages, both of which we recommend for use in the classroom. The first is a 'Scavenger Hunt', exploring the SDSS imaging data through the Navigate tool and learning about the types of objects observed. The second is a 'Constellation' activity, using the school's own plate, and using the survey data to find the holes on the plate which correspond to the 20 brightest objects. The activity results in a unique constellation for each school, composed of a random combination of stars, galaxies and quasars. By using redshifts as a measure of distance, each plate can then be turned into a three-dimensional representation of the constellation.

Expansion of the programme: We are currently expanding the programme to more Scottish schools and, via partner universities, to some English schools. The project has been awarded a 'Spark Award' from STFC, the UK's research council for astronomy and particle physics. We have also partnered with SSERC (Scotland's national support service for STEM teachers, and a major provider of professional learning) and the Ogden Trust (a UK charity promoting physics education). As part of the expansion of the programme, we are setting up a steering group of teachers and other stakeholders, and working to establish a community of practice amongst the teachers with plates.

A community of practice should allow teachers to share their best practice and resources, and benefit from each other's experiences. We encourage teachers to share their progress and provide spaces in which they can share experiences or ask questions. However, with the extreme time-pressures that teachers work under maintaining momentum requires regular input and active support from our team.

Impact & Evaluation project: Alongside the teacher workshops, an education research project began in 2021, in partnership with the School of Psychology & Neuroscience at the University of St Andrews. This aims to assess the impact of the 'Plates for Education' programme on teachers' self-efficacy and physics identity. An established body of research exists concerning artefact-based learning in different contexts, but there is less work on the use of the scientific artefact in the professional development of teachers. This project includes surveys and semi-structured interviews with teachers who participate in the 'Plates for Education' programme. Data from the first workshops are currently being analysed.

Future work: Unfortunately, SDSS plates are a finite resource, as the telescopes are now moving to a robotic fibre-placement system. While the existing plates can continue to be used for school engagement, there is also an interest in our team to identify other astronomy research artefacts that could bring new value to astronomy education.

Anyone interested to find out more, can contact sdss_plates@st-andrews.ac.uk regarding this project[1], or voyages@sdss.org to discuss work outside the UK.

[1]The work presented has been carried out at the University of St Andrews by Simon C. Reynolds, Rita Tojeiro and Anne-Marie Weijmans from the School of Physics & Astronomy, and Paula J. Miles from the School of Psychology & Neuroscience. The 'Plates for Education - Scotland' programme is developed and delivered by the University of St Andrews, using resources from the Sloan Digital Sky Survey; in partnership with SSERC, ESERO and the Ogden Trust; and supported by an STFC Spark Award.

Astronomy for Every Student

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

If we want to reach the greatest number of students and inspire them through astronomy the most effective method is to ensure astronomy is properly covered in the mainstream curriculum. Whilst not denying the value and role of specialist astronomy courses their reach will always be limited and indeed impacted by the lack of experienced teachers. By using astronomy as a context, we can illustrate examples where basic and key scientific concepts are used to help us understand the Universe. Examples from Australian curricula at both junior and senior high school levels are provided along with suggestions for integration into existing subjects.

Talk link: https://youtu.be/UGDudc2KpHY

Astronomy can be regarded as a "gateway science" and traditionally formed one of the quadrivium in a classical liberal arts education. We could consider a basic understanding of key astronomical concepts one component of what it makes a scientifically literate person. It is a subject that engages many children, has a wealth of inspiring content and imagery and tackles profound questions. Astronomy provides a rich contextual learning environment and as such can be used to cover a range of scientific concepts.

In considering what should be included in an astronomy curriculum recent work through the IAU has produced *Big Ideas in Astronomy* [1] – covering 11 Big Ideas with nested elaborations. It provides an excellent framework for those involved in curriculum design and astronomy education. Using this as a guide addresses the question of which key concepts should be included, the next question is then when should these be introduced in a curriculum?

A recent survey [2] of where astronomy is found in 52 curricula across 37 mostly OECD countries plus China and South Africa revealed that basic astronomy concepts such as seasons, day and night and eclipses are found in most science curricula. Relatively few however include modern astronomy topics including techniques and facilities. Even fewer specifically include cultural or Indigenous astronomy aspects.

There are examples of specialist subjects in astronomy that have been offered at high school level including *GCSE Astronomy* in England and previously *The Cosmology Distinction Course* [3] in NSW, Australia but these are targeted at a relatively or very small cohort of students. Whilst often highly impactful for these students in the broader reach of things they do little to increase the astronomical literacy of the general student population.

The most effective way in which all school students can be introduced to key astronomical concepts is through formal instruction as part of their general science education. This therefore requires that astronomy is a component of the required science curriculum. At the primary school level, foundation to Year-6 science is often covered as an integrated subject with technology. At the high school level, science is generally presented as an integrated, compulsory subject to the Year 10 level. In the higher years of high school (Years 11-12) Science may now longer be a compulsory subject and is typically offered as more specialised discipline subjects such as Biology, Chemistry, Physics and Earth Sciences. Given that Science is often only compulsory to Year 10 level it makes sense to include astronomy concepts in curricula for all students up to Year 10. Note though that astronomy does feature in some countries within elective senior physics and earth and environmental science courses.

An example of where astronomy has been included in the F-10 compulsory science curriculum is in the Australian Curriculum, Science. The development of an Australian Curriculum [4] was formalised in 2009, hitherto each State and Territory was responsible for their own curriculum. The curriculum is an online document, allowing for regular updates. Whilst intended as a national curriculum it is still up to each State and Territory as to how they implement the curriculum, leading to some variation across the nation.

The Foundation to Year 10 Science curriculum [5], currently at version 8.4 in Science as of November 2022, includes astronomy concepts at several year levels. The curriculum has three strands, *Science Understanding*, *Science as a Human Endeavour* and *Science Inquiry Skills*, plus some General Capabilities and Cross Curriculum Priorities. Within the Science Understanding strand, astronomy concepts are specifically presented as descriptors in Earth and space sciences content in the foundation Year 1, Year 3, Year 5, Year 7 and Year 10 levels.

Examples include:
Year 3: *Earth's rotation on its axis causes regular changes, including night and day (ACSSU048)*
Year 5: *The Earth is part of a system of planets orbiting around a star (the sun) (ACSSU078)*
Year 7: *Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth and the moon (ACSSU115)*
Year 10: *The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe (ACSSU188)*

Each content descriptor is provided with examples of how to address the requirement. In addition to these specified descriptions teachers are encouraged to incorporate science inquiry skills such as graphing, observation, communication and examples of science as a human endeavour – learning about a specific astronomer for example, in covering a topic. One of the Cross Curriculum Priorities is *Aboriginal and Torres Strait Islander Histories and Cultures*, an area where there is now a wealth of material on their astronomical understanding making astronomy an excellent area to address this requirement.

Inclusion in the core, compulsory science curriculum for schools is an effective step in building an astronomically literate society but is not enough in itself. Teacher professional learning matched with relevant, pedagogically sound resources and activities are two other essential steps.

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How Students Explore Space With Slooh's Online Telescope and Our Standards-Aligned Learning Activities

Speaker: John H. Boisvert, Slooh, USA

We have created a scalable way for an unlimited number of students to explore space with online telescopes at premier observatories in the Canary Islands and Chile. Our opportunity lies at the intersection of digital education and the new space age that is inspiring educators to look for ways to incorporate space exploration into the curriculum. Astronomy is a gateway science that inspires students to learn scientific reasoning. With our hands-on, standards-aligned, experiential learning activities, Slooh takes students beyond simulation to collect and analyse their own data as they master a new, real-world domain. Before Slooh, only science educators with a passion for astronomy could bring space into the classroom. Now any educator can do it!

Talk link: https://youtu.be/N_aVIS6E25o

Slooh's Online Telescope is an astronomy platform whose mission is to rebuild our collective connection to the night sky and Universe using our ten powerful, robotic telescopes situated around the world. This contribution will cover how students explore space with Slooh's Online Telescope and our standards-aligned learning activities, Quests. Quests are interactive learning activities that challenge students to use Slooh's Online Telescope to collect and analyse data to form their own conclusions. Quests teach students how to explore space in a self-directed manner while completing learning activities that challenge them.

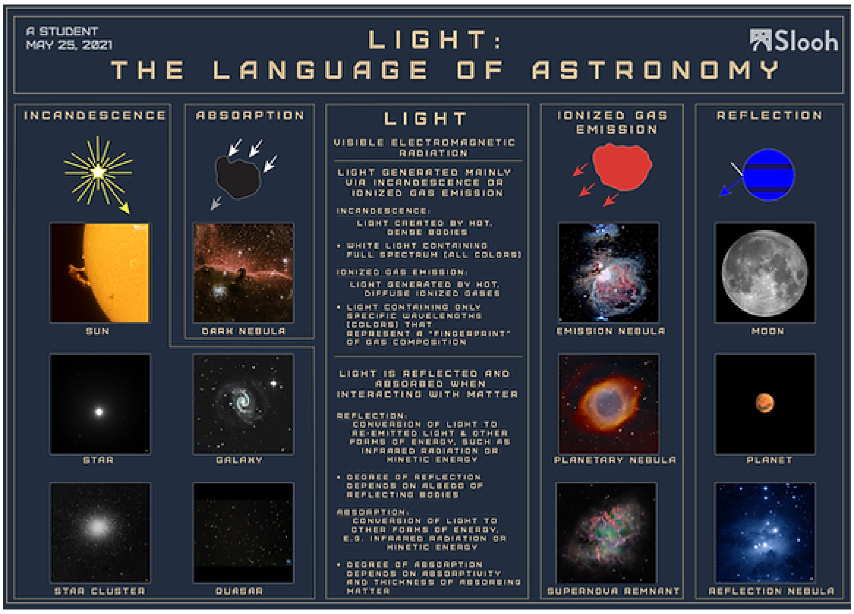

Figure 1: Example infographic made in the *Light: the language of Astronomy* Quest. The images were all captured with Slooh's telescopes.

A Slooh Quest culminates in creating a poster-sized infographic that showcases the students' images captured with Slooh's Online Telescope (Fig. 1). These personalized infographics generate a spirit of accomplishment for the student while providing an easy tool to recall the content they learn while on the Quest. In some cases, their infographic poster incorporates their responses to questions in the Quest. Since students use their own captured images, every student poster is unique. This flexibility allows students to explore their artistic expression and create something that speaks to them and for them.

Our ten online telescopes broadcast live from our Flagship Observatory at the Institute of Astrophysics of the Canary Islands and our Chile Observatory in association with the Catholic University of Chile.

Students, especially in secondary school, are cut off from the night sky and the rest of the Universe due to many factors, such as light pollution and difficulty with using set-up telescopes. Slooh's Online Telescope and our Quest Curriculum are an equitable way to bring the Universe back to the students so they can engage with space and gain a cosmic perspective. Before Slooh, only science educators with a passion for astronomy could bring space into the classroom; now, any educator can do it.

Quests are coherent, well-sequenced, experiential learning activities. They use Slooh's Online Telescopes to capture images of celestial wonders while learning about specific aspects of astronomy, history, anthropology, arts, and other STEAM topics—keeping students engaged and excited to learn. A remarkable aspect of astronomy is that it touches on many subjects and topics. Therefore, Quests inspire the learning of scientific reasoning in an exciting and engaging way. Astronomy is a gateway science that uses the phenomena captured in telescopes to inspire and encourage students to think scientifically.

Quests are a great way for students of all levels to stay engaged on the platform because they give students structure and provide goals for learning and capturing images for their collection. Students follow in the footsteps of professional astronomers, from learning about their captured objects in Slooh's real-time telescopes to planning and executing authentic observational astronomy missions. Students consider factors that may affect their mission outcomes, such as the weather, object altitude, the Moon's location, and more. Students are encouraged to tune in to see their image automatically processed with colour in real-time by our patented system as more and more light is collected.

Quest Objectives are laid out at the beginning for students to know the main points they are about to learn. Every Quest step has a set of vocabulary terms that students will learn. Lexile levels help differentiate the text so that more students can access the material.

These are some of the ways students learn on Slooh with Quests. Students complete reading exercises, data collection planning & execution, data & image analyses, quantitative & qualitative questions, and more as they progress through the Quest self-guided activities. They learn how to obtain, evaluate, and communicate the information they learn. Assessment within Quests comes in multiple-choice, fill-in-the-blank, and free-response questions that encourage critical thinking and require problem-solving skills. The output is clear if the student answers correctly or incorrectly, and inquiries support learning the material. Other flavors of assessment found throughout Slooh's Quests are mathematics walk-throughs that ensure students understand the reasoning behind certain equations and why they work with specific units. Fail-first free-response questions encourage students to use their reasoning skills to explain certain phenomena before learning about the topic and updating their responses afterward. Scaffolding questions that keep students on track and build upon their understanding. Students learn how to use observational evidence to construct arguments and how to develop, create, and use models while planning and carrying out authentic scientific investigations.

Slooh has Learning Progressions of Quests depending on the class an educator is teaching. These learning progressions are compact and address education curricula standards. With these progressions, educators can look at their syllabus on what they are told to prepare and then use these Learning Progressions to assign the relevant topics.

Slooh has curricula standards addressed for every Quest. Our Quests have addressed NGSS Performance Expectations, Disciplinary Core Ideas, and Science & Engineering Practices. We have also aligned them to the Common Core State Standards for Reading & Writing Science & Technology and Common Core State Standards for Mathematics. We recently addressed the physics & astronomy Texas Administrative Code—TEKS—for our High School Quests. In addition, our Quests are aligned with the OpenStax Astronomy Textbook.

We make it easy to implement Quests in the classroom using the Teacher Resources available for each Quest. Educators can assign Quests to students on the platform and monitor their progress using their classroom Workspace.

The Slooh platform is more than just an astronomy platform. It's a STEAM platform that uses astronomy to engage students and prepare them for their future careers while fostering a spirit of collaborative citizen science. Please attend this talk to hear and see more!

Astronomy and Space as a Gateway to STEM Education in India

Speaker: Mila Mitra, STEM and Space, India

STEM (Science, Technology, Engineering and Math), is an educational concept, essential for the future. It emphasises critical-thinking, interdisciplinary, hands-on, and real-life based applications. Astronomy is a great way to teach STEM because it is the basis of all sciences and is interdisciplinary. A problem faced is that astronomy and space are not counted as curriculum subjects, in countries such as India. STEM & Space has designed sessions that tie in primary curriculum subjects such as physics, math, biology, geography, and computing to space related hands-on activities, which make it possible to interest students and also directly address curriculum topics, thus finding endorsement from schools and teachers. In this contribution, we will give examples of this correlation.

Talk link: https://youtu.be/fBNaiYK4iqc

STEM (Science, Technology, Engineering and Math) is an educational concept, essential for the future. It emphasises critical-thinking, interdisciplinary and real life based applications. Astronomy is a great way to teach STEM because it is the basis of all Sciences and interdisciplinary. In this contribution, we explore how this can be taken forward in India.

India is a country with a large population, diverse in languages and economic structure. Being a very old country, superstitions and astrology are still prevalent in the community. Science is not representative of the society and building scientific temperament is essential. Education is recognised as a good way to embark in a career pathway that will lead to good jobs, so schools focus on good results in competitive exams. Students do pursue science, engineering and medical fields but mostly because they lead to good careers, and not due to a passion for STEM.

It is important to nurture an interest in STEM subjects as these will be the careers of the future. All around the world, it is now a goal to increase the numbers of students who pursue STEM careers to prepare students for the 21st century skills. As newer technology emerges, there may be new careers 10 years later that do not even exist now. Astronomy and space fascinate students. Movies and social media are full of space wonders. Astronomy is relevant to the current world and problems all around us – seasons, navigation, climate change, satellites. Astronomy is fun and students see it as a cool subject. This natural attraction towards space and astronomy should be tapped upon to attract students to STEM subjects. Hence, astronomy should be included in education.

In India, currently, astronomy is not taught at the school level, in fact, it is only at the postgraduate level. So, it can be introduced in schools as an activity. The Indian government, also recognising the importance of space education has recently included space in the tinkering labs in which schools can get funding. A problem faced is that astronomy and space are not counted as curriculum subjects, in countries such as India. Hence, one needs an approach to tie it into curriculum so schools will also adopt this. They can be connected to the curriculum by connecting space related observations and phenomena to curriculum based STEM.

STEM & Space, a niche educational institute in India has been working to tie in STEM education to space and astronomy. We have designed sessions that tie in primary curriculum subjects such as physics, math, biology, geography, and computing to space-related hands-on activities, which make it possible to interest students and also directly address curriculum topics. This helps in getting endorsement from schools. All of our sessions are hands-on to make it exciting.

Sessions created by STEM and Space that tie in STEM teaching through space topics include:

- Light and Spectroscopy – Through studying spectra of stars to understand their composition – learning about spectra, dispersion, spectra of different light sources

- Astrobiology – the search for life in the universe teaches about why Earth is unique, what parameters define life and search for life elsewhere

- Giant Moon and Mars maps – learning about different terrains and compare it to Earth

- Satellites – Making models to understand their parts and their functionality

- Volcanoes and their layers on other planets — understand age and composition of different layers can help students understand terrains and volcanoes on Earth

- Topography — creating contour maps from topography of other planets can help students understand geography and terrains as well as what topography and contours mean

- Programming concepts — Programming in languages such as scratch where they try to replicate real world scenarios like a Hohmann orbit. Students also understand how satellites take images and use false colouring for visual representation

In summary, STEM and Space has the objective to create exciting, innovative and hands-on sessions about space related topics that can be correlated to curriculum subjects to include more schools and students.

Stargazing Live!

Inspiring with semi-live astronomy data: teaching curriculum topics using smart education tools.

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

Collaborators: Joris Hanse (NOVA), Dennis Vaendel (Freelance science writer), Marco Kragten & Bert Bredeweg (Smart Education Lab, Amsterdam University of Applied Science), Steven Bloemen (Radboud University), Marieke Baan (NOVA), and Paul Groot (Radboud University).

Stargazing Live! aims to capture the imagination of students of all ages with live and interactive planetarium lessons incorporating semi-live data from the Dutch MeerLICHT and BlackGEM telescopes. For upper secondary school level, lesson activities have been created to accompany the planetarium shows using the interactive digital tool DynaLearn. The lessons challenge students to model key curriculum concepts linked to the telescopes and their science. The lessons were created using a co-creation model – led by science education experts with significant input from astronomers, astronomy outreach/education professionals and physics teachers. The project is now in the classroom testing phase and final products will be shared globally via the planetarium and NAEC networks.

Talk link: https://youtu.be/5FGbaHJhWUY

Project overview: Stargazing Live![1] started in early 2021 with the aim of bringing semi-live real scientific data into the classroom. The data will come from the small optical telescopes MeerLICHT (http://www.meerlicht.uct.ac.za/) and BlackGEM (https://astro.ru.nl/blackgem/), both owned and operated by Radboud University. MeerLICHT is based in South Africa and performs optical follow-up for the radio telescope MeerKAT. The BlackGEM array is currently being built in La Silla in Chile. The telescope design is the same as MeerLICHT but eventually there will be an array of 15 telescopes. The scientific aim of BlackGEM is to quickly respond to, and observe, the optical counterparts of gravitational wave detections. Each night the telescopes upload all of their data to Nijmegen where it is processed automatically and is available for use within 20 minutes.

The target group for the project is upper secondary school physics students (16-18 yrs) studying at the highest level in the Netherlands (pre-university education). As such, they cover some advanced topics in astrophysics. The main product is a new lesson for the NOVA network of mobile planetariums which visit around 250 schools across the Netherlands annually. The project uses recently taken real data to help explain curriculum topics related to the science goals of the telescopes. We are also producing a short, full-dome film about the telescopes and their science goals. Planetarium modules are written in a way in which it is easy to modify the content for other age groups.

[1]The project is funded by a grant from the Dutch Research Council NWO-NWA.

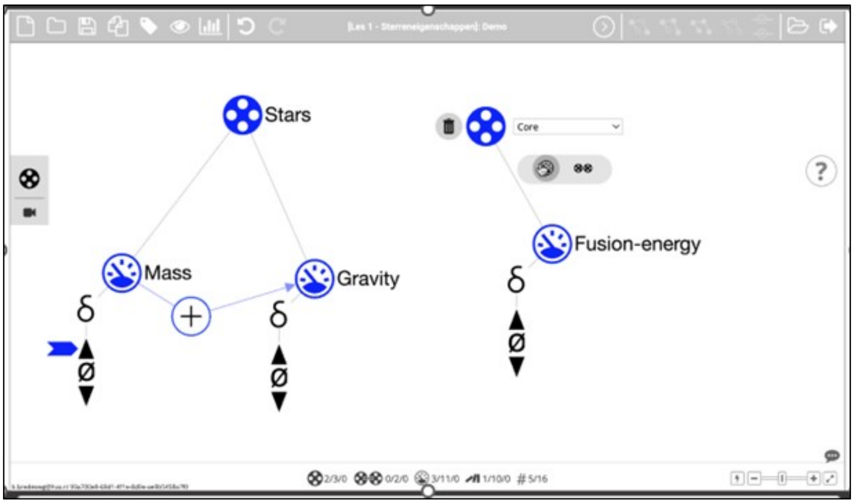

Figure 1: The first steps of the diagram om stellar properties in the DynaLearn tool.

The accompanying lesson activities (16-18 yrs) use the interactive digital tool DynaLearn (`https://www.dynalearn.nl/`). The lessons challenge students to model key curriculum concepts linked to the telescopes and their science. The lessons were created using a co-creation model – led by science education experts with significant input from astronomers, astronomy outreach/education professionals and physics teachers. The full project is now being extensively tested in secondary schools and once ready, will be shared in English and Dutch.

Lesson activities: The lessons teach curriculum concepts using concept modelling in the interactive digital tool Dynalearn. The lessons challenge students need to think carefully about the how key curriculum concepts work. Students work independently through a workbook. Teachers can monitor progress via an instructor interface. The tool provides automated feedback, but teachers can also give feedback via a chat function or of course, live in the classroom. We have created two lessons, one on the balance of processes within a star and one on stellar properties. Figure 1 shows the first steps in the model for the lesson on stellar properties.

Modelling versus mapping: There is a subtle difference between concept modelling and the more frequently used concept mapping. In concept mapping, students create something that looks like a mind-map. Students break a concept up into sub-concepts and the relationships between them. A concept map is static and the relationships between sub-concepts are descriptive e.g., 'the earth has a shape'.

Concept modelling is a more active representation of concepts. As with concept mapping, students must split a concept into sub-concepts and create the relationships between them. However, instead of creating a static, verbal representation, the relationships which students place between sub-concepts behave as in the scientific formulae behind them – they are causal dependencies between quantities. For example, as the wavelength of light from a star increases, the star becomes redder – Wien's law. The tool therefore not only allows the students to recreate the model (the static part) but allows the student to simulate the model to both check relationships are correct and to discover how other parameters change. Figure 1 shows the first steps in the concept model for the lesson on stellar properties.

Testing and evaluating in real classrooms: The project is now in the testing phase. Both the planetarium and DynaLearn lessons are being tested in 11 classes in 3 secondary schools across the Netherlands (n$\sim$275). The project will also be presented at a large physics teacher conference plus at other events. The planetarium lessons are being evaluated using observations and interviews with teachers and students. Evaluation of the DynaLearn lessons also includes a short pre- and post-test on the lesson concepts. Results will be available shortly and will be used to fine-tune the lessons and planetarium content.

Looking to the future & sharing: Once the lessen and planetarium content have been fully tested, the products will be made freely available to the community in both Dutch and English.

Spazio allo Spazio: An Educational Project Promoting Connection and Inclusion Through Sky and Space

Speaker: Andrea Ettore Bernagozzi, Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA), Italy

Collaborators: Anita Alfano, Paola Sarti, Elisabetta Rurale, Michela Sala, Luigia Sironi, Luca Montani (Lower Secondary School "E. Fermi", IC Villasanta), Ludovico Bernasconi (Department of Aerospace Science and Technology, Politecnico di Milano), Jean Marc Christille, Paolo Calcidese (Astronomical Observatory of the Autonomous Region of the Aosta Valley), and Mario Zannoni (Department of Physics "G. Occhialini", Università degli Studi di Milano-Bicocca)

Spazio allo Spazio (SaS) is an interdisciplinary educational project launched in 2010 by the lower secondary school "E. Fermi" in Villasanta, Italy. At its core lies the strong belief that space exploration and sky observations can promote the active and inclusive involvement of students, making them protagonists of their own learning. Stargazing connects people and cultures of different countries and epochs, constituting a significant part of our common heritage; the astronauts must acquire new skills to control a challenging and unpredictable context in space, just like a disabled person in everyday life. The contribution explains how SaS addresses these topics from the point of view of teachers (mostly not of scientific school subjects), researchers of several institutions as well as students.

Talk link: https://youtu.be/93NcuxxTZj8

Spazio allo Spazio (SaS) is an interdisciplinary educational project launched in 2010 by a group of Italian teachers from the Lower Secondary School "E. Fermi" in Villasanta, a small town near Milan, Italy. It stems from the strong belief that crossing the boundaries of school subjects can help students (11-13 years old) to learn in a more effective way, by increasing their awareness of links and connections between different fields of knowledge. In addition, this approach allows students to widen their vision beyond the lessons in the classroom, favouring confrontation with other cultures and people, that is a prerequisite to promote inclusion and a better understanding of ourselves, too. And which horizon is wider than the horizon of the sky and space? The teachers identified *Astronomy* and *Human Space Exploration* as the areas where to place an innovative set of educational activities, described below, as to give “space to space”, as the English translation of the Italian name of the project states. The fascination that stars and space spontaneously exert on the students – and the teachers! -– is another important element for this choice.

During a dozen years, the project has established many collaborations with scientific institutions and researchers, especially from the Department of Physics “G. Occhialini” of the University of Milan-Bicocca (Unimib) and the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA), to develop educational initiatives fit for the age of the students and with a solid scientific background.

Educational framework: The aim of the project is to improve self-awareness and students’ potential by focusing their attention on topics connected with inclusion and career orientation. The educational activities are related to several school subjects, from STEAM to physical education and foreign languages, to strengthen the skills and competences. Students are invited to participate in activities with a proactive and creative attitude, in order to be protagonists of their own learning, not merely viewers or end-users. To do that, astronomy and human space exploration have shown to be key ingredients, in particular to involve and engage disadvantaged students, like immigrants or students with special needs and disabilities.

Astronomy: People of different cultures, countries and epochs have always looked at the sky, telling legends about the starry sky and studying celestial phenomena. All these stories and notions have been transmitted through the centuries, constituting a significant part of our cultural common heritage. The myths of the constellations and the science facts of modern astronomical observations show young participants how we are all under the same sky and share the same attitude towards the stars, as human beings and “citizens of the cosmos”.

Human Space Exploration: Despite their extraordinary physical and psychological preparation, astronauts (for simplicity, with this term we consider cosmonauts and taikonauts, too) have a surprising, unexpected similarity to disabled people. In fact, the astronaut, while experiencing microgravity and weightlessness during a space mission, must acquire new skills and be able to adapt to a challenging and unpredictable context just as a disabled person needs to do every single day! The example of the astronaut underlines that everyone has to face challenging objectives and thus develop the abilities needed to perform that task; in other words, rather than “disabilities”, we should think of “different abilities” that can be defined according to specific circumstances. The link between space and different abilities, an intuition developed by the teachers for SaS, has subsequently been confirmed for example by the ESA call for Parastronauts.

Learning activities: The activities carried out use different methodologies and tools, with the aim of making students protagonists of their learning and stimulating their curiosity for knowledge. The project includes: meeting with researchers, also via the SaS YouTube channel, including connections with Arctic and Antarctic stations (Dirigibile Italia, Concordia); visits to scientific and

Postcards from *Spazio allo Spazio*, with a collage of different activities carried out during the first twelve years of the educational project.

technology centres in Europe (EAC in Germany, CERN in Switzerland); the design of the posters of the events, as well as of logos and messages printed on weather balloons provided by Unimib and launched from sites in Italy and Antarctica; radio contacts with the ESA astronauts aboard the International Space Station; meetings with ESA, NASA astronauts, Roscosmos cosmonauts. Students are directly involved together in these events as presenters and exhibitors of works about the experiences they lived, speaking and writing in Italian, English, French, while constantly updating the SaS blog.

In particular, experiences with astronomy included observations of the Sun and the night sky at the OAVdA, in the first *Starlight Stellar Park* in Italy, and remote connections from South America with ALMA researchers; experiences with Human Space Exploration included lectures by astronaut trainers, in order to study the consequences of microgravity on human body, and training in swimming pools with the use of specific equipment under the supervision of the specialised staff of Disabled Divers International-Italy. Students can share positive emotional relationships under the same sky, and find collaborative and compensatory strategies to deal with the challenges.

Finally, throughout the project, students have the opportunity to gather valuable information about personal experiences and training paths of the experts, in not only the field of science and technology, but also arts, sports (Paralympic athletes), literature, languages, music, public administration and international diplomacy. These interactions encourage the adoption of significant role models, leading to more conscious and responsible choices for the prosecution of their studies in the higher secondary school and the university.

The project *Spazio allo Spazio* is expression of a school open to the world (or even the cosmos!) in contact with other realities and contexts, that cares about the individuality of each person, gives the students stimulating opportunities, and values science and technology, especially astronomy and human space exploration, as a way to improve social relationships, inclusion and commitment.

Young Stars of Tomorrow

Speaker: Marcelo de Oliveira Souza, Universidade Estadual do Norte Fluminense and Louis Cruls Astronomy Club, Brazil

Collaborators: Róbson Vasconcelos Chagas (Louis Cruls Astronomy Club, Instituto federal Fluminense), Isabely Gonçalves Mariano (Universidade Estadual do Norte Fluminense, Louis Cruls Astronomy Club), Caroline Oliveira do Carmo (Louis Cruls Astronomy Club), and Binha Ferraz Daumas (Universidade Estadual do Norte Fluminense, Louis Cruls Astronomy Club).

The main objective of the project is to find and stimulate young talents for science among students from public schools located in remote regions and in popular communities in municipalities in the north region of Rio de Janeiro State, Brazil. Because of the project, new, modern, and creative materials were developed to be used in the teaching and popularisation of astronomy with space exploration as a motivating element. The use of astronomy and space exploration as the main theme of the project is associated with our experience of more than 30 years carrying out projects for the teaching and popularisation of Science. Since September 30th, 2021, we developed the project in 55 public schools with the participation of more than 1,800 students.

Talk link: https://youtu.be/ndFUzY0jRAQ

The objective of the project Young Stars of Tomorrow was to find and stimulate young talents for astronomy among students from public schools located in remote regions and in popular communities in municipalities in the North region of Rio de Janeiro State. Because of the project, new, modern, and creative materials were developed to be used in the teaching and popularisation of astronomy with space exploration as a motivating element. The use of space exploration as the main theme of the project is associated with our experience of more than 30 years carrying out projects for the teaching and popularisation of astronomy.

The project has a main axis that is the development by the students of creative missions of exploration of the Moon and beyond. From this central axis, we trained students in physics and astronomy, in programming for apps development and in the development of 2D and 3D illustrations and animations. With this knowledge, students were motivated to develop creative projects for exploring the Moon with the use and development of new technological resources. During the process, we identified new talents among students and invited them to join the project development team. They were the catalysts of the teaching-learning process. We used design thinking implemented within a project-based learning as the pedagogical methodology. We presented challenges as a basis to encourage student participation in groups and to develop projects in a collaborative way. The students involved in the project had at the end of the activity, knowledge, and technological mastery to develop innovative products initially aimed at the educational area and scientific popularisation. The main target of the project were students in the eighth and ninth years of elementary school and in the first year of high school.

From the end of September 2021 to October 2022, the project was developed in 55 public schools located in six cities in the northern region of the state of Rio de Janeiro in Brazil. We had a total participation of more than 1,800 students.

Two days of activities were developed in each school. The central axis of the project is "Creatives Missions to the Moon and beyond". Students participated in the first day in special and interactive classes associated with the following topics: Basic physics and astronomy, topics of space exploration with an emphasis on the history of NASA, activities of sky observation and identification of planets and constellations and challenges for the future of space exploration. After the participation in these activities, it is proposed that students develop a creative project for a trip to the Moon with the aim of building a base on its surface. Each student received a printed copy, of the challenge notebook and of the passport to the Moon. The main objective is that students at the end of the activity understand the main challenges to be overcome to send astronauts to the Moon and beyond and build a base for the astronauts to live on the Moon. In the second day at the school, we make presentations associated with the history of computing and artificial intelligence, development of algorithms and use of programming language to create applications for smartphone and tablets, use of virtual environments, brief History of audiovisual arts and its technological evolution and the development of digital 2D and 3D images and animations. After completing the activities at the school, outstanding students were invited to participate in special training in one of the areas covered by the project. After a long selection process, nine students were chosen to compose the project development team.

During the project, applications for smartphones with an android system and an animation series about astronomy with six episodes were developed. For the animation series, four characters were developed that make up the 'Stars of Tomorrow' team. The animated series was broadcast by a local television station. Among the applications developed there are six associated with astronomy or with tools that can be used for the dissemination of astronomy: creative scientist, variable brightness, space, quiz of astronomy, light pollution and challenges. Now, because of the project, we have groups of students motivated to develop astronomy activities in 55 schools located in six cities.

The "Young Stars of Tomorrow" project is supported by the United States Consulate General in Rio de Janeiro through their 2021 Annual Program Statement.

All the animations, photos, reports, and video reports of the development of the project are available at: `https://www.youtube.com/clubedeastronomia`, on Facebook (@louiscruls) and applications developed are available at: `https://passeiopeloceu.org/app/`.

ExoMaths

Speaker: Manuel Felipe Núñez Díaz, IES Alcalde Bernabe Rodríguez, Spain

Basic mathematical concepts are behind many research fields, but complexity lies in connecting them to a classroom activity. In this contribution, I show a beautiful example where 12 year old students link calculation of circular areas with transit method for detecting exoplanets (geometry and astrophysics). The power of free mathematical software (GeoGebra) to model stars and exoplanets with plane circles, compute the visible area of the star through the animation, and plot the results to compare with observational data. The final outreach video is developed and explained by the siblings Elisa and Hugo.

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

This teaching project was developed in the first and second courses of the Secondary School "Alcalde Bernabé Rodríguez" (Tenerife, Spain). The main idea was to link basic math knowledge in geometry and calculus with cutting-edge research on exoplanets detection. To this aim, the students used GeoGebra, a powerful, interactive and free mathematical software.

In these first years of secondary school, students learn how to calculate areas of several plane figures (triangles, squares, rectangles, circles, etc.) and composite ones. There is a special composite figure, the circular ring, that regards to the phenomenon of exoplanet transits. They study that the ring area is the result of the outer circle area minus the inner circle one. It is easy to link this exercise with the transit method, were both circles represent a star and an exoplanet, respectively. Although the star and planets are 3D objects, we observe them like circles, and the telescopes capture the total brightness during the different phases of eclipses, and therefore, the conceptual idea is applicable because when the exoplanet crosses in front of its host star's disk a small amount of photons are blocked.

GeoGebra allows to simulate the phenomenon with its geometry tools and command line. Firstly, star (R=10) and planet (r=0.25) are generated with the command circle, where the star centre is fixed at the origin, but the planet moves across the disk along X axis depending on the value of the variable s (see Table 1). After modifying the colours of the circles, background plot and hidden the axis, the simulation resembles a real planet transit (see Fig. 1).

Secondly, three situations are defined to determine the visible area of the star. If the planets is outside the disk ($|s| > R+r$) the visible area is equal to the star's area (A1), or inside the disk ($|s| < R-r$) the visible one is equal to the difference between star and planet areas (A2). Otherwise, the planet would be entering or egressing the star disk, where only part (an arc) of the planet is occulting the whole star (see Table 2).

Finally, the ratio between the visible and the star areas is plotted for each point (D) of the

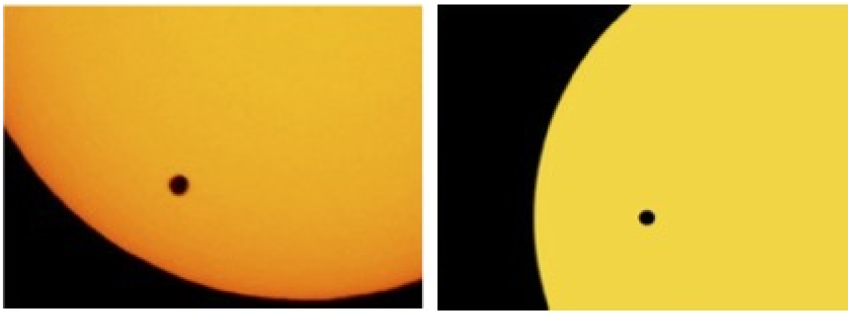

Figure 1: Transit of Venus across the Sun disk (left) and a screenshot of the GeoGebra simulation on this project (right).

trajectory, reproducing the shape of the observed light curve during exoplanet transit (see last two rows in Table 2).

Students could play with the planet radius to understand the changes in the observed light curve. The larger the radius, the deeper the curve. They can also compare their curve with the scientific ones from astronomers. Moreover, it would be great to discuss some open questions in class, for example, how do we know the star's radius?, how many exoplanets are discovered?, could they have a civilisation?, etc.

This activity was a great opportunity for students to understand that behind simple or boring school activities there is a potential mathematical tool for discovering far away exoplanets, which may not be captured as a direct image with current telescopes.

For more details visit the Instituto GeoGebra de Canarias: `http://sinewton.es/igcan/`.

Table 1: GeoGebra commands to generate the simulation of a planet crossing the host star disk.

Name	Definition	Value
R	Star radius	10
r	Planet radius	0.25
s	Planet horizontal position	0
Star	Circle((0, 0), R)	$x^2 + y^2 = R^2$
Planet	Circle((s, 0), r)	$(x - s)^2 + y^2 = r^2$

Table 2: GeoGebra commands to plot the "light" curve.

Name	Definition
A_1	Area(Star)
A_2	Area(Star) - Area(Planet)
AB	{Intersect(Star, Planet)}
A_3	Area(Star)-Area(Arc(Planet, AB(1), AB(2)))
$A_{visible}$	If(abs(s)$>=$R+r, A_1, If(abs(s)$<=$R-r, A_2, A_3))
P	$A_{visible}$ / A_{star} x 100
D	(s, P)

Teaching Astronomy, Physics and Mathematics Through the Use of SalsaJ software

Speaker: John Carlos Mora, Expoastronomy, Colombia

SalsaJ allows students to analyse and explore real astronomical images in the same way as professional astronomers do, it allows scientific analysis with data extracted from the images. It introduces photometry workshops, spectra analysis, and sunspot measurements in the classroom activities. In this contribution we demonstrate the use of SalsaJ software.

Talk link: https://youtu.be/0bDu3p9mDZ0

People are fascinated with astronomy since ancient times, the desire to answer questions about our nature when contemplating celestial bodies in the sky and its images cause astonishment in children and adolescents, motivating them to investigate and give answers resulting in amazing discoveries. The SalsaJ software allows us to learn astronomy by doing astronomy, walking through concepts of physics, mathematics, chemistry, geometry, allowing astronomy to be the key that opens the door to scientific knowledge from an early age.

“Astronomy should be part of the educational system”, according to the doctor in astronomy, John R. Percy. He said this in his speech for the International Astronomical Union Symposium in 1998. “In a school context, astronomy demonstrates an alternative approach to the ’scientific method’: the observational versus the theoretical approach. It can attract young people to study science and engineering and can increase public interest in and understanding of science and technology; this is important in all countries, both developed and developing” [1, 2]. Education is very important and fundamental to improve the processes of inclusion, by using astronomy education to ensure that children, adolescents and adults have access to quality scientific learning [3].

Likewise, Jymie Matthews, a Canadian astronomer from the University of British Columbia, invited Costa Rican parents and educators to take advantage of people’s natural interest in seeing the sky to encourage this and other scientific vocations, and explained, “Astronomy is fascinating and is the most suitable tool to engage all people, especially children, in science. Nothing can change the experience of observing the sky and learning to be amazed by the environment and wondering what lies beyond the stars and why: that is pure science!”.

LCOGT Las Cumbres Observatory: We are Global Sky Partner of Las Cumbres Observatory LCOGT ongoing educational project Expoastronomy LCOEPO2021B-008, which gives us the opportunity to use scientific equipment [5], providing us with telescope time, which we use to take astronomical images. Using their scientific data, we can carry out our research and develop courses and workshops for teachers and high school students who normally do not have access to these resources (Fig. 1).

SalsaJ software: SalsaJ is a free software developed specifically for the EU-HOU project, easy to install and use. It allows students to display, analyse and explore real astronomical images in the same way as professional astronomers do, making the same kind of discoveries that leads to real enthusiasm for science. In addition SalsaJ has been translated into many languages: English, French, Spanish, Italian, Polish, Greek, Portuguese, Swedish, North Sami, Arabic, Chinese [6] (see Fig. 2).

Photometry, spectrum analysis and geometry: Salsaj software is an excellent tool for astronomical use, it allows us to perform several scientific analyses in a practical and simple way, with the data extracted from the astronomical images captured by the different robotic telescopes located around the planet in countries such as Australia, South Africa, Canary Islands, Chile, United States, from the Las Cumbres LCOGT Network, which allow us to bring to the classroom in an affordable way, South Africa, Canary Islands, Chile, United States, of the Las Cumbres LCOGT Network, which allow us to bring to the classroom in an affordable way research and workshops on Photometry (Fig. 3), Spectrum analysis (Fig. 4), Sunspot measurements (Fig. 5) and RGB image processing. Workshops with teachers should be increased so that more students have the opportunity to work with SalsaJ and thus generate more scientific knowledge.

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Figure 1: Expoastronomía Global Sky Partner LCO Las Cumbres Observatory. https://lco.global/education/partners/expo-astronomy/

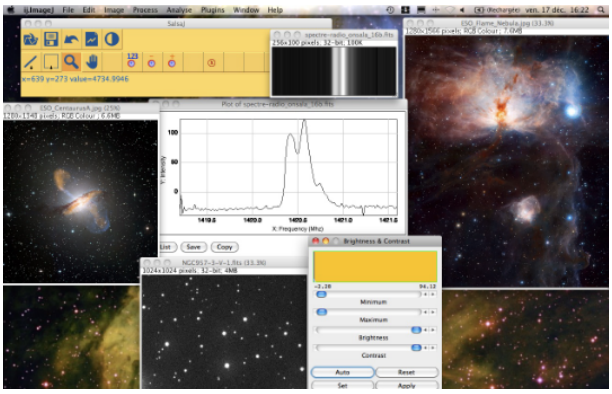

Figure 2: SalsaJ Software Menu

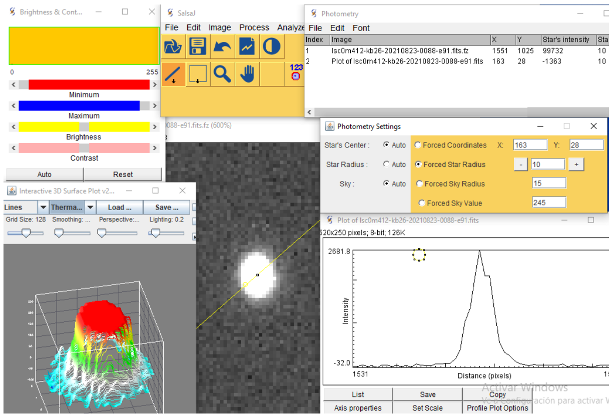

Figure 3: Photometry in 3D, Binary Star TYC 8409-975-1 Expoastronomy, Las Cumbres Observatory LCOGT, 0.40 mtrs, Cerro Tololo Observatory

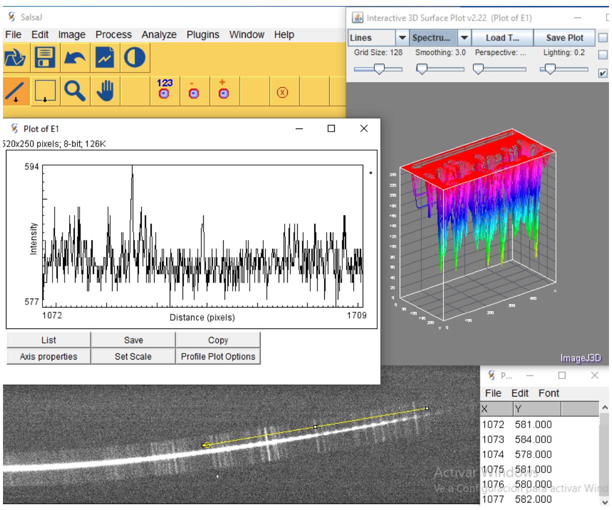

Figure 4: Spectra analysis in 3D, Object: L745-46^{a}, Las Cumbres Observatory LCOGT, 2 mtrs, Siding Spring Observatory

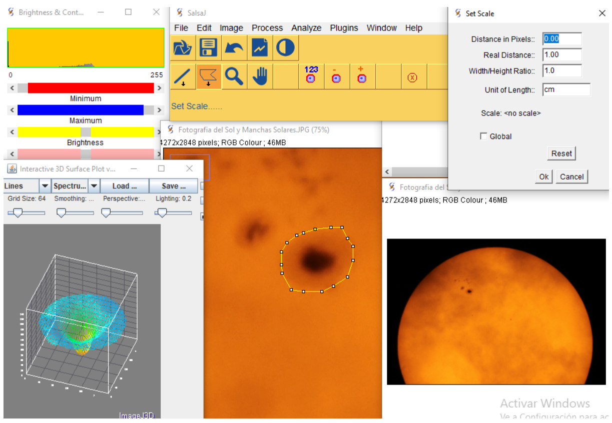

Figure 5: Measurement of sunspots J. Mora, J. Henao, Celestron, 0.20 mtrs, Medellin, Colombia

Bringing the Universe to Your Classroom – The Faulkes Telescope Project

Presenter: Sarah Roberts, Faulkes Telescope Project, Swansea University, UK

The Faulkes Telescope Project (FTP) aims to enthuse, engage and educate learners in STEM subjects using astronomy as the hook. Through our partnership with Las Cumbres Observatory, we provide free access to a global network of robotic telescopes for education. In this contribution we will describe the various research projects and activities that schools have undertaken with these facilities, including more arts-type projects rather than traditional STEM ones.

Poster link: https://astro4edu.org/siw/p115

The Faulkes Telescope Project provides free access to a global network of robotic telescopes for education through our partnership with Las Cumbres Observatory (LCO). We also offer free teacher CPD and resources for STEM education. The aim of the project is to encourage schools to carry out "real research in real time with real scientists".

School's work

Arts and Languages: The type of work carried out by schools using the LCO telescopes through the Faulkes Telescope Project varies greatly – for those schools and teachers starting out with using robotic telescopes, colour imaging is the first step in their journey of the Universe. By using free software packages such as SalsaJ or the GIMP, students can image various objects in space and create beautiful colour images in their classrooms. This has been done by a number of schools as part of their Art lessons. A school in Scotland also worked on making colour images as part of their French language lessons – they used Faulkes Telescope North in Hawaii to image objects from the French astronomer, Charles Messier's catalogue of deep sky objects. Once observed, the pupils created colour images, displaying them on a French language poster in their school.

Real Research: Once pupils and teachers have more confidence with using the telescopes, or for older schoolchildren, carrying out scientific investigations is the next step in their journey of astronomical discovery. Recently school children in Wales took images of the binary asteroid system Didymos in order to get images as part of NASA's DART (Double Asteroid Redirection Test) mission. The mission was a success, with NASA announcing they had managed to change the course of the smaller asteroid in this system of two – and the images obtained by the school children using the LCO telescopes were included in those images analysed by NASA scientists!

With the Faulkes Telescope Project, schools can spot new supernovae, catch a comet, gaze at galaxies and study the stars – free for all schools in Europe to use, the sky really is the limit when you join us on our journey through the Universe!

Bridging the Gap Between Subjects and Educational Levels Using Space Educational Activities

Presenter: Danijela Takač and Ana-Marija Kukuruzović, Pantovčak elementary school, Zagreb, Croatia

In the Croatian educational system there is a big gap in science curriculum between middle school and the start of high school. This gap results in insufficient student knowledge of STEM subjects. Students that have attended astronomy as an extracurricular subject have been more successful in bridging that gap. We will showcase educational activities that help bridge this gap by exploring astronomy using scientific concepts summarised in a project called "Exploration of Mars". We will show activities that explore the connection between gravity, terraforming and atmospheric structure of the planet, hydroponics, assembling, programming and "driving" a rover on Mars, space tourism. These activities allow us to explore scientific concepts beyond the construct of the national curriculum.

Poster link: https://astro4edu.org/siw/p116

We are trying to use astronomy to connect different subjects and bridge the gap between educational levels. In the Croatian educational system, there is a big gap in science curriculum between middle school and the start of high school. This gap results in insufficient student knowledge of STEM subjects. Students that have attended astronomy as an extracurricular subject have been more successful in bridging that gap. We will display educational activities that help bridge this gap by exploring astronomy using scientific concepts summarised in a project called "Exploration of Mars". Activities were cross-curricular so apart from physics, biology, chemistry, engineering they also include physical education and arts.

In the Croatian educational system throughout the years, in our experience, while teaching science and astronomy, we have identified a big gap in science curriculum between middle school and the start of high school, as well as the gap between high school and university. This

Figure 1: Primary students training as astronauts “for mission to Mars”, experiments with material density for middle school students, and high school students measure Earth’s magnetic field and gravitational acceleration and compare with values on Mars.

curriculum gap results in insufficient student knowledge of STEM subjects. Students that have attended astronomy as an extracurricular subject have been more successful in bridging that gap. Our research has shown that students who attend astronomy classes as early as the start of middle school are even more successful. Throughout the years teachers who have integrated astronomy activities throughout cross-curricular science subjects such as physics, chemistry, technology and biology have increased students’ interest in STEM subjects and those students tend to apply to technological universities or space-related ones.

Astronomy: Towards a Didactic Focused on Interdisciplinarity

Presenter: Alvaro Folhas, NUCLIO, University of Coimbra, Portugal

Astronomy arouses curiosity for the unknown and mobilises all areas of knowledge, promoting an interdisciplinary vision in which, the whole is always greater than the sum of the parts. A project focused on astronomy normally has the natural involvement of mathematics and physics, but it can also cover chemistry, biology, geography, ICT and the arts, especially if we associate it with astronautics and space exploration, the great levers of scientific and technological development, spilling over into our daily lives in the technologies we use today. It is important to bring astronomy to school, through its inclusion in the curriculum, or through small projects capable of mobilising and reinforcing learning, while helping to develop skills.

Poster link: https://astro4edu.org/siw/p117

Since the beginning of this century, the European Union, UNESCO, OECD, and several other international organisations have shown great concern about the gradual disinterest of students

Figure 1: Measurement of the shadow of a vertical pole at solar noon to determine Earth's perimeter (Eratosthenes' experiment).

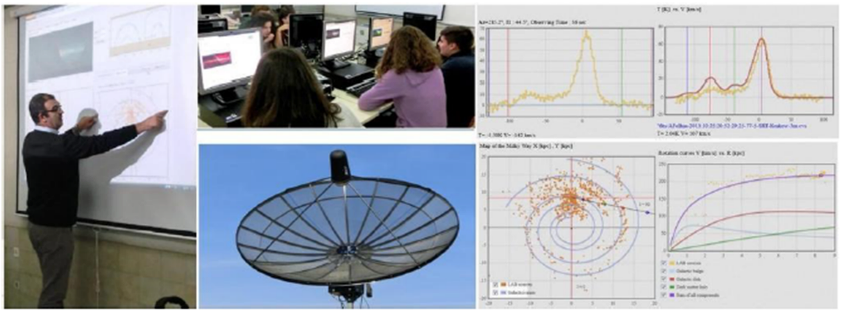

Figure 2: Use of robotic telescopes in the classroom to deepen knowledge of different subject areas.

in science. Science is more fundamental than ever before to overcome the enormous challenges of the future, and that is why measures must be taken to engage students in science. The growing needs of scientists and engineers and the vastness of information that surrounds us require that students acquire skills along with structuring and significant knowledge.

Astronomy and space sciences can be a lever to make science and technology more appealing in school, not only for the fascination they exert on all ages, but also for the breadth of knowledge domains it covers, from social sciences to pure and applied sciences to cutting-edge technology, allowing cross-curricular and multidisciplinary activities. But the school must reinvent itself, creating interdisciplinarity spaces that help to better interpret reality, giving substance to concepts and providing discovery. Activities such as the experience of Eratosthenes (determining the perimeter of the Earth), mobilising knowledge not only in geography, physics, mathematics but also in history, arts and ICT. Students, through these hands-on and minds-on interdisciplinary activities, will become aware of the importance of knowledge and what can be done with it, especially when associated with the exercise of observation and scientific reasoning. But more than a challenge for students, it is a challenge for the schools in the way it will have to organise itself with the necessary plasticity to provide these spaces of interdisciplinarity.

Several other examples can be considered, based on observation and analysis combined with interdisciplinary knowledge, such as determining the solar diameter by projecting sunlight onto a target after passing through a pinhole, or using images of lunar and solar eclipses to determine the value of the sizes of the Moon and the Sun, as well as the distances they are from us.

Astronomy also enables a new approach to the scientific training of students and the development of skills – Teaching Science by doing Science. Access to robotic telescope constellations to record or study astronomical objects or phenomena, whether optical telescopes or radio telescopes, as well as participation in asteroid research campaigns allows a very high level of motivational and scientific experience to students. In addition to reinforcing their learning, they acquire structuring scientific skills and a clear idea of the importance of the method and critical observation. NUCLIO, together with several other partners, is developing activities for schools in projects such as LaSciL (Large Scientific Infrastructures Enriching Online and Digital Learning) or the IASC (International Astronomical Search Collaboration) among other projects, with training of teachers for the use of space and astronomy, combining teaching methodologies by inquiry and project based learning, for schools interested in adopting new approaches that point the way to the future.

But astronomy can provide more than scientific resources or concepts. It can help create a new perspective of a world without artificial barriers. To promote the idea that we are the ones who belong to the planet and not the planet that belongs to us. To embody the concept of the cosmopolitan as one who integrates the Cosmos. That is why it is essential to bring astronomy to the school.

Introduction to Stargazing and Image Processing with Automated Observation Stations

Presenter: Olivier Parisot, Luxembourg Institute of Science and Technology

Collaborators: Pierrick Bruneau, Patrik Hitzelberger (Luxembourg Institute of Science and Technology), Gilles Krebs, Christophe Destruel, Benoît Vandame (Vaonis)

Electronically Assisted Astronomy (EAA) consists of capturing images with a camera coupled to a telescope and then applying lightweight processing to display views of celestial objects. During the MILAN research project (funded by FNR in Luxembourg), we use automated stations of VAONIS for stargazing sessions, helping greatly to arouse the curiosity around astronomy. Firstly, participants can learn how to localise and then observe objects like galaxies or nebulae. Secondly, playing with settings like exposure time shows how image acquisition works. Thirdly, displayed live views continuously improve as data is accumulated, allowing to discuss the basics of image processing (SNR, alignment, stacking). Finally, participants can use raw data to practice image edition trough dedicated software.

Poster link: https://astro4edu.org/siw/p118

Figure 1: Observation of the Sh2_101 nebula with a Stellina automated telescope (night of 31/7/2022) [4]. The image on the left corresponds to a single 10s exposure frame and the image on the right is the result of the stacking of 340 frames (10 s exposure too).

During a stargazing session with direct observation through eyepieces and telescopes, it is not uncommon to have some disappointed participants, especially because of the lack of contrast and colour of the observed celestial targets [1, 2]. Without forgetting that during direct visual observation via a telescope, people with physical constraints will not be able to take full advantage of it (poor eyesight, handicap, etc.).

Nowadays, Electronically Assisted Astronomy (EAA) is widely applied by astronomers to observe deep sky objects (nebulae or galaxies) and planets [3]. By capturing images directly from an image sensor coupled to a telescope and applying lightweight image processing, this approach allows to generate enhanced views of deep sky targets that can be displayed in near real time on a screen (laptop, tablet, smartphone). EAA makes also possible to observe in difficult outdoor conditions, for example, in places heavily impacted by light pollution – deep sky objects almost invisible through direct observation in an urban or suburban sky become impressive and detailed.

Unfortunately, for those who want to start practising EAA, the implementation is not straightforward because a strong technical background is needed [1, 2]. In fact, EAA requires a complex hardware setup: motorised alt-azimuthal or equatorial mount for tracking targets (w.r.t the Earth's rotation), refractor/reflector with good-quality optic, CMOS/CCD dedicated cameras, pollution filters, etc. Depending on the apparent size of the celestial targets, a Barlow lens (for planets and planetary nebulae) or a focal length reducer (for large nebulae) is also required. Moreover, dedicated software like Sharpcap or AstroDMX are needed to control the camera and then deliver the live images on a display device.

This is where the use of automated observation stations makes sense. During the MILAN research project (MachIne Learning for AstroNomy), funded by Luxembourg National Research Fund, we use automated instruments provided by VAONIS to collect images of deep sky objects by using smartphones & tablets [3]. With these observation stations, required steps are automatised and transparent for the end-user: tracking, focus, capture, lightweight image processing, and then display. Thus, these instruments provide live images in different conditions (e.g. low or important light pollution) and with different parameters (exposure time and gain for each unit shot).

During outreach events or during outdoor workshops with a lay audience, the automation of tedious tasks makes it easy to address a wide range of subjects during live EAA sessions. Such automated telescopes allow to easily inspect the sky map and then explain how to choose the celestial sky targets that are visible according to the season and their position during the night. It is thus possible to show live views of visible objects (stars clusters, galaxies, nebulae) while describing their characteristics (e.g. apparent size, magnitude and even distance of the observed targets).

In practice, these automated instruments can be connected to several devices at the same time, so it is convenient to organise interactive observation sessions where each participant can easily observe the captured images. For the more curious, the usage of these observation stations allows at addressing advanced concepts. As a first example, participants can better understand how the image acquisition process works – by visually observing the impacts of capture settings like exposure time and gain. As a second example, it is visually obvious that the quality of the image shown on the screen increases as the station accumulates data, allowing to discuss the basics of image processing in astronomy (signal-to-noise ratio, images alignment and stacking). Finally, participants can retrieve the captured images (raw, unprocessed, or final) for further exercises in image processing – providing an opportunity to learn new techniques to make the most of the data captured trough dedicated open-source software. For example, SIRIL can be applied to stack the raw images while GIMP can be used to make the final images more attractive.

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Discussion summary

The panel discussion mainly focused on how to teach and include astronomy as part of other subjects in schools. It was highlighted that astronomy is an excellent context for cross-curriculum content and skills.

One effective way to bring modern science or new developments of astronomy to students is to build a collaboration between the classroom and a practitioner who could either be an experienced teacher or a scientist.

Many teachers mentioned that they found the astronomy to be a useful tool for engaging students. It was emphasised that astronomy can be easily linked to several topics within the already existing lessons, even in physical education classes (e.g. elliptical orbits) and teachers do not need to wait until astronomy is introduced as its own subject. Some ideas were shared to include astronomy topics in different schools, even with limited facilities. Some panellists shared ideas about using everyday, readily available teaching material, like a tree branch to understand trigonometry, an old CD/DVD to build your own spectrograph or even termite wings to show the diffraction pattern of sunlight.

It was also pointed out that "one person's scrap can be another person's treasure", i.e., recycle and reuse, for example, using an SDSS plate to view the eclipse (https://sdss3.wordpress.com/2015/03/20/sdss-scientists-in-europe-enjoy-eclipse2015/) and a local artist making use of transparency's of the night sky in their artwork.

Evaluation of the impact of lessons including specific astronomy related topics on student interest/engagement were discussed and how it could be used to convince local administrations/governments to add astronomy as an independent subject in the science curriculum.

Shared resources:

- Online virtual tour of the Rapid ASKAP Continuum Survey (RACS) that students can explore: https://www.atnf.csiro.au/research/RACS/RACStour/index.html.
- https://blog.csiro.au/sharing-sky-and-stars/
- http://passeiopeloceu.org/app/

Students in a Changing Climate: How Can Astronomy Help?

Session organisers: Eduardo Penteado (OAE Heidelberg), Asmita Bhandare (OAE Heidelberg), Anna Sippel (OAE Heidelberg), Violette Impellizzeri (Allegro Leiden, founding member of Astronomers for Planet Earth), and Colm Larkin (OAE Center Cyprus)

Session overview

Scientists and researchers from around the world share their experiences about discovering how astronomy helps us understand the changes occurring in Earth's many climates. This session also explores how astronomical activities can help predict the challenges and impacts those changes will have on indigenous populations around the world.

Cecilia Scorza shares the ideas behind the project "Pale Blue dot: Looking back at home". Kathryn Williamson presents methods developed for generating conversations on the issue of Climate Change for a range of demographics from students in universities to policy makers in West Virginia state's capitol, with a focus on breaking down cultural stigmas and discovering common ground. Anniek Gloudemans discusses the project "Life in the Universe" aimed at inspiring and informing the public about our Earth and our special place in the universe. Participants of this activity learn and relate to their own experiences and choices helping them appreciate the conditions and factors necessary for life and our life to exist.

Addressing issues such as gender, ethnicity and location, Christine Hirst Bernhardt presents her methodologies on guiding students to address the inequalities in Astronomy and the sciences in general. Exodus Chun-Long Sit describes an interdisciplinary project, ASTROx, which aims to go beyond the classroom connecting astronomy with other possible academic disciplines or subjects, based on Sustainable Development Goals. Mila Mitra illustrates how climate change and astronomy are connected and the impacts each has on the others and shows how climate change can have drastic impacts on ground-based observations and facilities. She presents some examples of activities to help younger students learn about climate conditions for planetary settlements and rising sea levels.

A message from Astronomers for Planet Earth (https://astronomersforplanet.earth/): https://youtu.be/lewxHQvbrFs (Talk by Violette Impellizzeri).

Talk contributions

Pale Blue Dot: Looking Back at Home

Speaker: Cecilia Scorza, LMU Faculty of Science, Germany

Climate change is the greatest global challenge of the 21st century. The high speed at which climate change is progressing poses an enormous problem. Neither flora and fauna nor humans can adapt that quickly to the change of environmental conditions. What can we astronomers contribute to raise the attention of students and their teachers to global warming? How can we link the fascinating astronomical objects with such a terrestrial issue? These questions are addressed in this contribution.

Talk link: https://youtu.be/zDJDtAK-02o

There is No Planet B: Engaging Students and Teachers in Climate Learning and Action

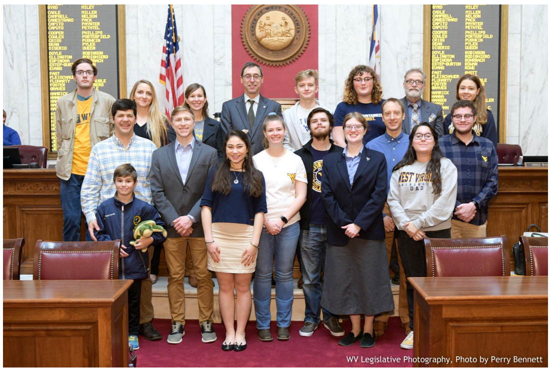
Speaker: Kathryn Williamson, West Virginia University, USA

Astronomy helps us understand planetary systems and it provides a big-picture perspective of ourselves as Earthlings. We can teach climate change through topics such as the greenhouse effect; however, understanding the science alone is not enough. We must empower students with solutions and help them use their voices and take action. I provide concrete examples of how we have done this in West Virginia, a coal state in the USA, through efforts such as a book club, podcast, field trip, and ongoing teacher training. I also invite participants to join "Astronomers for Planet Earth", a grassroots international effort by astronomers across the world to unite and speak up about climate change with the message that, "There is no Planet B".

Talk link: https://youtu.be/LxYliZnk-g8

Astronomy helps us understand planetary systems and it provides a big-picture perspective of ourselves as Earthlings. For example, we can teach climate change through topics such as the greenhouse effect. While early astronomers thought Venus would be a lush tropical paradise, we now know that Venus is a dire warning of a "runaway" greenhouse effect. We see that despite how much we may dream about exploring and habitating other worlds, creating a planet that can truly support us is only a distant dream. Even as we discover Earth-like planets orbiting other stars, the Cosmos is too vast; we cannot relocate anytime soon. Therefore, there truly is no "Planet B" that we could move to, if through some catastrophic event or our own actions, Earth were to become uninhabitable. It is imperative that, as educators, we help our students understand the degree to which we must care for our home planet. The topic of climate change has become fraught in the public dialogue, so teaching about it must go beyond science alone. Even if our students can describe the greenhouse effect in detail, they may not understand how to move towards the actions needed to change the way we live as Earthlings and care for the planet. We must empower students to see solutions, to use their voices and their skills, across all areas, and to move toward action and quickly.

For the past few years during my time as a college professor, I experimented with various ways of doing this in the state of West Virginia in the USA. West Virginia has a reputation for its once-thriving coal industry and extractive practices, which provided well-paying jobs for communities. Therefore, talking about climate change, and the importance of reducing our dependence on fossil fuels, can generate fear of job loss and economic security. In engaging in climate change discussions, my aim was to be sensitive to this history, and find and amplify the ways that West Virginia has the potential to move toward a "just transition", where coal communities are not left behind, but empowered to grow and thrive while solving climate change. Inspired by Katharine Hayhoe's TED Talk, "The Most Important Thing You Can Do To Fight Climate Change Is To Talk About It", my primary effort has been to generate conversations, and empower students and



Students and faculty at the WV State Capitol for a "Climate Education Day"

teachers to generate their own conversations, so we can break down these cultural stigmas and find common ground. The methods for generating these conversations were primarily through: a campus book club, a podcast, a field trip, and ongoing teacher training, as described below.

In Fall 2019, I taught a climate change book club at West Virginia University, in which students read 3 books related to climate change, "The Two-Mile Time Machine: Ice cores, abrupt climate change, and our future" by Richard B. Alley, "Earth in Human Hands" by David Grinspoon, and "Renewable: One Woman's Search for Simplicity, Faithfulness, and Hope" by Eileen Flanagan. These books generated many discussions and reflections, and students were inspired to do a final project to go beyond the course. We collectively decided to create an accompanying podcast, called "WVU Climate Conversations". Each of the 7 students in the class hosted an episode in which they interviewed a climate expert from our campus or state. Episode topics included how to live sustainably in the dorms, how to navigate political conversations that involve climate change, how to think globally and locally, and how to learn from historic droughts and famines. The podcast is available on all major platforms. Later, in February 2020, I organised a field trip for students and faculty to visit the state capitol for a "Climate Education Day". Rather than lobbying for a specific bill or policy, the aim was to showcase the climate change research and educational efforts that are happening in our state. Students and faculty hosted stations, such as an ocean acidification demonstration with purple cabbage juice as a pH indicator, a greenhouse effect demonstration with an infrared camera, an interactive carbon footprint calculator, a scientific research poster about tree ring data as a proxy for climate change, and others. Lawmakers cycled through the stations and talked with students and faculty to learn more about climate change. Overall, the conversations were productive, and students reported feeling excited and empowered to continue such efforts in the future.

A more sustained effort over the last 4 years has been engaging teachers in climate change learning and action. In 2019, a team of astronomy educators started the "West Virginia Climate Change Professional Development" (WVCCPD) project, which has so far engaged over 100 teachers in at least 1 climate change activity, learning event, or course. Teachers who take the WVCCPD course earn continuing education credits. The course is divided into 3 parts: 1 for climate change physical science and social science, 1 for climate change communication and youth empowerment, and 1 for action, in which teachers engage their students in a full lesson plan with an action component. Additionally, for the last 2 years, we have hosted a "Public Service Announcement" (PSA) contest, in which students submit video and audio clips, our grants then pay to broadcast on local television, radio, and news channels. We estimate that these PSAs have reached tens of thousands of local residents. The winning students have also been invited for interviews on local news channels, and they have received much praise and accolades from their schools and communities.

I hope these activities inspire other astronomy educators to try to engage their students, peers, and community members in climate change learning, dialogue, and action. We can all work to develop our identities as Earthlings who are empowered with the knowledge that there is no "Planet B". This is the message of a new grassroots group of hundreds of astronomers around the world who join together as "Astronomers for Planet Earth" and are speaking out about climate change. Please join us!

Life in the Universe: Using Astronomy to Teach Primary School Children About Climate Change

Speaker: Anniek Gloudemans, Leiden Observatory, The Netherlands

Astronomy is a powerful tool to fascinate children about our Universe and offers a new perspective on the climate discussion by making them realise how unique our Earth is compared to other uninhabitable planets and why we have to protect it. Therefore, as a part of the sustainability committee at the Leiden Observatory in The Netherlands, we have developed a 5-day lesson program designed for primary school students (9-12 years old) to discover the principles of astronomy, conditions for life in the Universe and on planet Earth, and sustainability. In this contribution, I discuss the goals of the project, the challenges that we faced, and our outlook on the future.

As a part of the sustainability committee at the Leiden Observatory in The Netherlands, we have developed a 5-day lesson program designed for primary school students (9-12 years old). The main aim of this project is to fascinate children about the Universe and make them realise how unique our Earth and climate are from a cosmic perspective. Education on the climate change crisis is an urgent topic on the Sustainable Development Goals agenda and highly relevant for schools in the Netherlands. Astronomy is a powerful tool to fascinate children about our Universe and offers a new perspective on the climate discussion by making them realise how unique our Earth is compared to other uninhabitable planets and why we have to protect it.

The idea is that we achieve our goals through play. The children work in groups, over the course of 5 lessons/days. Each group is assigned to a planet or moon in the Solar System and is asked to design and build an alien that can live on it (based on a workshop from astroEDU). For the first part of the activity they will be actively gathering information about the planet/moon assigned to them. Once they know enough, they will start the design and construction of the aliens.

Our alien mascot is called Dumpy!

For the second part of the activity, once the aliens are finished, they will then have to test the survivability of their alien using testing stations to mimic for example cold, wind, or high gravity.

All group activities will be guided by the school teachers and astronomy educators who will help introduce concepts like habitability and adaptation. Once the children have finished their design of the alien and passed the testing phase, they will present it to the other groups on the last day. The teachers/educators will conclude the activity with a discussion on why the Earth is so special for us, about habitability and the interconnectedness of life in the Universe; we depend on our planet's health, which is part of a larger ecosystem.

Our pilot project has been very successful and with the support from the ET Outreach award we have been able to further develop the lesson material, which will be made available online for everyone to use in the near future (see https://www.universiteitleiden.nl/leven-in-het-heelal/over-leven) .

Astronomy as a Bridge to Equity

Speaker: Christine Hirst Bernhardt, University of Maryland, USA

This contribution explores the integration of space science technologies to demonstrate global change in a tangible way, emphasising modelling, data analysis and problem solving. Astronomy is presented as a moderator between all systems of the terrestrial sphere, and a means by which to make local and global decisions. Participants are provided with tools and lessons to foster STEM identities and build bridges between science, community, and the classroom. Utilisation of astronomy with a climate lens can unify learning from other contents, while providing opportunities to explore the evidential sources of knowledge of our world.

Talk link: https://youtu.be/S8e5ekNFD2o

Earth and Space sciences encompass the most neglected realm of science education in the United States, as well as the lowest representation of Women and People of Colour. For over a century, high school science coursework has minimally included biology, chemistry and physics, integrating Earth sciences in middle grades and eliminating astronomy. There has been no national test, curricula or standardisation for astronomy coursework. The scarcity of course offerings and absence of Advanced Placement or IB courses have relegated coursework to university settings, by that time the moment to select a STEM field has likely passed. Secondary and primary environments are critical for the formation of a STEM identity, particularly amongst girls and students of non-dominant groups. This contribution explores the integration of space sciences in formal education settings to foster STEM identities and build bridges between science, community, and the classroom. Utilisation of the space environment can unify learning from other contents, while providing opportunities to explore the evidential sources of knowledge of our world.

The United States is currently at a pivotal crossroads in science education; the recent inclusion of Earth and Space content into newly adopted national standards, particularly in earlier grades, provides a unique opportunity to contextualise science learning. This is especially important following a year of remote learning, and more so for students in urban environments. In 2013, the National Research Council adopted the Next Generation Science Standards (NGSS), which identified and assigned equal weight to the content areas of life (biology), physical (chemistry and physics) and Earth and Space. This is a stark difference from the previous 100 years of education, and allows for a drastic restructuring of the science course sequencing. There is now a far greater emphasis on Earth-Space systems across all grade levels, reflecting the interdisciplinary nature of the field. The exposure to meaningful and relevant science activities can provide an inclusive environment to traditionally marginalised students who do not see the real world applicability of science in their lives.

This session will explore astronomy education as a tool of equity. Students in urbanised settings may have even less academic exposure to astronomy and space sciences through a vicious cycle of deficit thinking and systematic oppression. A pedagogy of poverty has been the dominant narrative in which high teacher turnover in urban schools fosters a reliance on curricularising [science] coursework to a minimum set of knowledge requirements, which remove connection and application to local context and settings. In urban schools, this curicularisation may look like non-local examples, unrelatable representation, and a failure to incorporate areas of relevancy and urgency from daily life into the classroom. This can further complicate the incorporation of space sciences, which may seem abstract, complicated, and unnecessary. One can only imagine the magnification of this separation following a year of remote, removed learning mediated by a screen. By providing mechanisms of access to space sciences connected to local environments, educators can facilitate authentic learning experiences to previously excluded students in these fields. Astronomy education, particularly in Western Nations, has the potential to disrupt colonial narratives while providing greater access to 21st century skills. Participants will be provided a space to explore the integrations of astronomy to foster and facilitate equity and justice, while connecting to the natural world. Some issues may be personally challenging to address, such as environmental racism and bias. This session will be highly interactive and allow participants to explore the use of satellite imagery to address social justice issues in their region and abroad. Participants will develop their own activities connected to their individual spaces which they can immediately use in formal K-12 education settings.

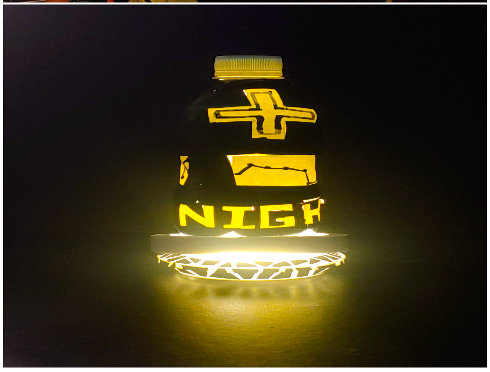
ASTROx Sustainability: Student-Led Social Innovation Project Achieves Sustainable Development Goals

Speaker: Exodus Chun-Long Sit, Starrix, Hong Kong

Sustainability is an urgent problem that students will always be aware of the climate change from the textbooks. Beside traditional lessons in the classroom or group project presentation, how can we imply sustainable actions with astronomy education? ASTROx is an interdisciplinary project that aims to connect astronomy with other possible academic disciplines or subjects, based on Sustainable Development Goals. The contribution will showcase a student-led social innovation project about dark-sky advocacy and science communication, solving real-life issues in the community. Students had explored different ways to raise the awareness of urban light pollution by outdoor classrooms, design thinking lessons and hands-on experience.

Talk link: `https://youtu.be/FQiN17HqD40`

It is so grateful to start a new student-led social innovation project called "Hong Kong Light Pollution Rescue Team" about dark-sky advocacy, and solving real-life issues in the community.



This is star walking activity in Wong Tai Shi, Kowloon District (Central City Regions) organised by Starrix Hong Kong. Besides traditional stargazing tours or sidewalk astronomy, light pollution field trips are highly recommended for astronomy educators and science communicators to organise. It would be a great opportunity to make the participants aware of the issues of urban light pollution and stargazing etiquette.

Regarding the research conducted by the Physics Department at the University of Hong Kong, as a part of the Hong Kong Night Sky Brightness Monitoring Network (https://nightsky.physics.hku.hk/en-hk), the measurements of average night sky brightness in the evening near the Tsim Sha Tsui Area (the central city region of Victoria Habour, Hong Kong) is 1200 times brighter than the darkest sky, comparing to the international standard of the International Dark-Sky Places. Even though the area of Hong Kong is really small, due to its light pollution issue, it could still be able to be seen on the global night sky map and the observation from the International Space Station. Therefore, Hong Kong's Light Pollution Rescue Team organised a light pollution field trip in Tsim Sha Tsui, which is an urban area with lots of skyscrapers near the Victoria Habour (Fig. 1a). It aimed to allow the team members to have a social observation of outdoor lighting designs and be aware of the seriousness of artificial light at night in different disciplines in our daily life.

Inspired by the issues defined by the United Nations' 17 sustainability development goals, design thinking experiential workshops were also organised to transform social observation into practical projects and learning outcomes with teachers' guidance and scaffolding of lesson designs. To have a better understanding of the relationship between outdoor lighting designs and urban light pollution, the "Light Pollution Kit Set" for dark sky advocacy and science communication was designed by Exodus Chun-Long Sit as a supporting educational tool (Fig. 1b). It aimed to allow participants to make prototypes of dark sky friendly outdoor lighting shields by using recycled plastic bottles (Fig. 1c), enhancing experiential learning activities and peer interactions at the Light Pollution Rescue Team. There is no right or wrong in the brainstorming stage of the design thinking process, and accepting open-minded discussions. It was great to have motivated the next generation to share their unique ideas and insights from the field trip and learned from other people's successful cases for making adjustments to their original designs.

The Light Pollution Rescue Team had also contributed to several international festivals, such as International Dark Sky Week by the International Dark-Sky Association, Earth Hour by the World Wildlife Fund, UNESCO's International Day of Night, and Dark Sky Awareness Month by the IAU Office for Astronomy Outreach (OAO). And we had also taken part in a student showcase of learning outcomes during the DreamStarter Fair 2022 (Fig. 1d). Night sky advocacy and science communication is a long-term goal to create a better world, raising more public awareness of sustainability developments and climate change issues.

Including Climate in Astronomy Education

Speaker: Mila Mitra, Co-Founder, STEM and Space, India

Collaborator: Aditi Tomar, Senior Educator, STEM and Space, India

Is our planet in danger from changing temperatures and rising sea levels? In this contribution, we discuss educational activities to enhance student's awareness on climate change, specifically the rise in sea-level and how it has started impacting life on Earth. Sea level is rising, in part, because increase in greenhouse gases contribute to melting glaciers on land which are adding to Earth's oceans. Sea ice is not a significant contributor to sea level rise. Thermal expansion of water is also a major contributor. Understand these points through two investigative activities. We discuss how such images of sea levels are taken through satellites and do a trending activity

Talk link: `https://youtu.be/Gr0u5s-Q8R0`

Figure 1: A model of a settlement on Mars

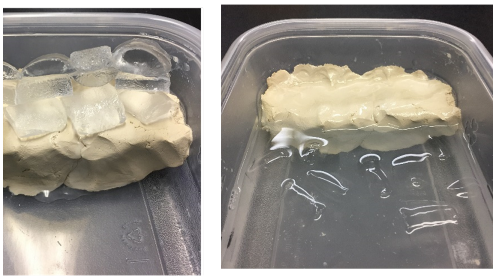


Figure 2: Experiment to study contribution of land ice vs water ice melting to sea level rise

Figure 3: A model of the layers of the atmosphere

Climate change is one of the biggest issues in today's society. Children and youth have a lot of concerns about their future related to the effects of climate change. Should astronomers include climate as a topic along with Astronomy and space education? There are several reasons why they should do so. Climate is a natural extension to what astronomers teach. Earth sciences and atmosphere are already an extension that astronomers include. Learning about space translates to knowledge about our Earth.

Astronomy already assumes some knowledge of atmospheric conditions, in situating their observatories. Telescopes are located in places which are dry and at higher locations, to avoid water vapour that can trap heat and to improve the seeing conditions. Astronomers also try to avoid light pollution. So, we are already conveying points about understanding our atmosphere.

Studying about terrestrial planets, their atmosphere and their terrain help students understand the atmosphere and changes on our planet. For example, students learn about Venus and why it is the hottest planet due to an atmosphere that has greenhouse gases and traps heat. Through planet history of terrestrial planets - planets like Mars that may have evolved from liveable to unlivable climates and may have had water earlier, they may also understand that such an evolution is possible on our planet. This can be extended to an understanding that not only planetary changes but human actions can cause climate changes.

Astronomy also studies why our Earth is the only known habitable planet in the Solar System. Due to its optimal location, Earth has temperature, has water and an atmosphere. As astronomers study other potential locations and their conditions, students can understand the parameters of life and how major changes factors can affect life. They may also realise that it will be hard to find a planet B.

We already teach about satellites which gather astronomy data. So, students are versed in astronomy data and analysis. We can easily extend this to studies of the Earth and atmosphere and show climate related data to students and help them study trends.

Astronomers are popular and are trusted as they are less controversial and not political. Astronomers reach a lot of people, there are many astronomy clubs and amateur astronomers and astronomy education is popular. Hence, astronomers already have eager communities they can spread the word to.

STEM and Space is an educational institute in India that has been active in fostering interest in STEM (Science Technology Engineering and Maths) education through the domains of space and astronomy. Seeing the interest of today's youth in climate, we have started extending our educational sessions to include atmosphere and climate.

In this contribution, we also present a few such activities. These include studying the atmosphere and other conditions on Mars towards building a settlement there. Another activity involves doing simple experiments to understand climate change problems such as sea level rise. For younger students, activities introduce them to our atmosphere and how it protects us and greenhouse gases.

Discussion summary

The quote "*Many little people, in little places, doing little things, can change the world*" by Eduardo Galeano perfectly sums up the efforts highlighted in this session. All the projects discussed were born locally, independently of each other but despite the different approaches there was a synergy of everyone finding ways to address the global issue of climate change.

The panellists shared that it is easy to capture the attention of students already interested in astronomy and use that as a starting point to also educate them about the effects of climate change, importance of sustainability and individual actions. Introducing various activities at school in astronomy, geography, chemistry, biology, environmental science or even art courses can be extremely powerful and have ripple effects in engaging a wider community. One can use local and visible events such as light pollution in cities, flooding, extreme temperatures etc. to point out the impact of climate change. Students can bring home what they learn from these activities and share it with their families. This also empowers students, builds their self-esteem and their resilience for any challenges that may come up and helps them understand that their voice matters in making a significant impact.

Students will eventually be the future decision-makers and voters and it is important that they understand what climate science is, how it impacts them and what they can do about it. It is also crucial to equip teachers with more resources and allow them to make flexible and informed decisions. This would then enable them to help students find the right tools to take action because many of them are unaware of ways to utilise the knowledge that they have. Creating platforms for amplifying student voices is necessary. Moreover, the use of social media to address climate change can be beneficial, especially for boosting efforts by the younger generation.

The main take-away point from the contributions and lively panel discussion was that open conversations about climate change with a more positive and hopeful outlook and developing different creative forms of outreach to spread awareness can prove to be a very useful tool. Furthermore, it is also important to find ways to reach people from different backgrounds and older generations, so that we can translate ideas to actions more efficiently.

The audience echoed the message that all the activities discussed seemed like they are too small to make a difference, but change happens in small steps and bringing up children who know climate change to be an indisputable fact is immensely powerful.

Resources shared during the discussion:

- Collection of resources for "Carbon Footprint of the Astronomy Profession", which includes concrete examples of observatories changing their carbon footprints: https://astronomersforplanet.earth/public-resources/, https://klimawandel-schule.de/en
- Design your Alien: https://astroedu.iau.org/en/activities/1303/design-your-alien/, https://www.universiteitleiden.nl/leven-in-het-heelal/over-leven

- West Virginia Climate Change Professional Development project: https://sites.google.com/view/wvclimatechangepd
- Globe Observer: https://observer.globe.gov/do-globe-observer
- All We Can Save - Truth, courage, and solutions for the climate crisis: https://www.allwecansave.earth/anthology

Gravitational Waves, Black Hole Shadows and Exoplanets: Can We Make a Place for Cutting-Edge Results in Schools?

Session organisers: Anna Sippel (OAE Heidelberg), Niall Deacon (OAE Heidelberg), Stefano Sandrelli (OAE Center Italy), Surhud More (OAE Center India), and Rosa Doran (NUCLIO, Portugal)

Session overview

Cutting-edge science is not only exciting and interesting but also acts as an important introduction to both, scientific content, and the challenges of doing science. Many of you will have first become fascinated by astronomy thanks to hearing about a new, ground-breaking result. But cutting-edge science is difficult to teach about: By definition, it is a rapidly changing topic, and the latest results today may eventually become redundant in the future. This constantly shifting scientific landscape makes the incorporation of cutting-edge results into lessons and curricula tricky.

In this session, we discuss how to introduce cutting-edge results in schools, and highlight the challenges faced by astronomers, science communicators and teachers in building educational content for scientific areas such as gravitational waves, black holes shadows, and exoplanets into the curriculum.

Ten speakers will be sharing their challenges and achievements in this difficult but important task: From introducing a robust educational framework to a module connecting the astrophysics of black holes to the properties of the waves to using observational facilities and real data of exoplanets for project based and interactive learning activities, a very broad range of topics is covered. Exoplanet data are also used for active-learning tasks for students in mathematics and physics classes while another project focuses on using astronomy to implement transferable skills particularly prevalent in IT and maths. Highlights from collaborations such as LIGO Virgo KAGRA as well as EHT are presented, to convey gravitational-wave astronomy to students and teachers around the world, and we also get an introduction to Space Scoops, which brings news from across the universe to kids around the world.

Combining Design-Based Research and the Model of Educational Reconstruction in Astronomy Education

Speaker: Magdalena Kersting, University of Copenhagen, Denmark

How can we make a place for cutting-edge astronomy research in schools? Which methods ensure that our instructional activities work in diverse educational contexts and become relevant to students? While cutting-edge topics such as gravitational waves, black hole shadows, and exoplanets have great potential to motivate students, the novelty of these topics poses challenges for teachers and instructors. This contribution will present a robust educational framework, the Model of Educational Reconstruction. I will argue that we can combine this framework with design-based research methods to develop instructional resources that engage students and successfully convey the subject matter. Case studies in general relativity education will illustrate the efficacy of this approach in astronomy education.

Talk link: https://youtu.be/vq9cobm3AzI

Science classrooms are critical places to foster positive attitudes in science and prepare for future career choices. Since astronomy, applications of physics in space, and unsolved physics problems are popular topics among students (Kersting et al., 2021; Sjøberg & Schreiner, 2010), cutting-edge astronomy can realise the potential of formal science education to motivate and inspire students. Besides, these topics often create a sense of personal relevance among students and have been found to engage girls and boys alike (Kaur et al., 2020; Kersting et al., 2021; Sjøberg & Schreiner, 2010). Nevertheless, the novelty of cutting-edge research can present teachers and educators with challenges. Usually, little is known about students' learning processes, including possible alternative conceptions, in these learning domains. Additionally, teachers can seldom rely on previous experience in teaching such cutting-edge topics.

It is here that physics and science education researchers can contribute to making a place for cutting-edge astronomy results in schools. By integrating the perspectives of scientists, teachers, and students, education researchers are well positioned to develop instructional approaches and learning resources that convey new science concepts successfully while also engaging students in diverse contexts. A promising approach for synthesising these different perspectives and designing successful science instruction is combining the Model of Educational Reconstruction and design-based research (Kamphorst, 2021; Kamphorst & Kersting, 2019; Kersting, 2019).

While the Model of Educational Reconstruction serves as an overarching framework to reconstruct novel scientific topics from an educational perspective (Duit et al., 2012), design-based research provides an iterative methodology for developing and testing learning resources effectively (Anderson & Shattuck, 2012). The Model of Educational Reconstruction takes its starting point from the assumption that "science subject matter issues as well as student learning needs and capabilities have to be given equal attention in attempts to improve the quality of teaching and learning" (Duit et al., 2012, p. 13). In recent years, physics and science education researchers have proposed educational reconstructions of special relativity (Kamphorst et al., 2021), general relativity (Kersting et al., 2018), dark matter (Woithe & Kersting, 2021), nanotechnology (Laherto, 2010), non-linear systems (Stavrou, 2015), and climate change (Niebert & Gropengießer, 2013), among others.

Design-based research (DBR) tries to create instructional materials that function well in the "messy" environment of everyday school education (Kamphorst & Kersting, 2019). design-based research methods depend on several iterations of development and testing conducted in close cooperation with teachers and educational practitioners. Such cycles of iterations include problem analysis, solution creation and design, implementation, and subsequent assessment. Learning designs are continuously updated and improved because of teacher input, student views, and new research on learning processes. This constant re-evaluation and adaption of instructional resources are particularly useful when researchers and educators try adapting the material to different learning contexts and age groups.

While the Model of Educational Reconstruction provides perspectives on the subject area, teaching, and learning (theories), design-based research provides a methodological structure to include practitioners and design hypotheses. Common to both is the iterative approach in which classroom studies inform the design of learning resources. Examples of such iterations on specific learning resources and an educational reconstruction of general relativity can be found in (Kersting, 2019). In summary, combining the Model of Educational Reconstruction with design-based research methods can help us leverage the potential of (cutting-edge) astronomy in formal education.

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Bringing Gravitational Waves Into the Classroom Using Streamlit

Speaker: Sumeet Kulkarni, University of Mississippi, USA

Physics concepts surrounding oscillations and waves at the middle- and high-school level can be introduced in a more enticing way by hooking students with cutting-edge research in gravitational waves. We have developed an online, interactive module that serves this purpose using Streamlit, a python-based library. The module connects the astrophysics of black holes to the properties of waves that they emit, forming a toolkit for teaching the same in an engaging way. It can be self-completed, used in an online lesson, or interactively in a classroom module. Formative assessment questions are provided at a conceptual level.

Talk link: `https://youtu.be/j7WcEimtJtI`

The LIGO Science Education Center (SEC) in Livingston, Louisiana, USA was established to increase science engagement and provide access to quality physics education at one of the two Laser Interferometer Gravitational-wave Observatory (LIGO) sites in the country. Through on-site school field trips and detector tours, the focus of LIGO SEC has always been to connect fundamental physics involved in the detection of gravitational waves to the concepts being taught in schools. A lot of this involves hands-on demonstrations that build upon certain instrumental challenges encountered by LIGO. For instance, the mirrors used inside the interferometer are controlled using electrostatic actuators – this is not too different from how the build up of static charge enables us to displace light objects. Another example involves using pressure and vacuum demos, given that the 4-km long LIGO arms contain one of the largest vacuums in the whole world, to avoid scattering of the laser light that they carry.

With the onset of the COVID-19 pandemic, SEC field trips had to be conducted virtually. This change was accompanied by a creative redesign of the hands-on activities using materials that could be shipped or easily procured at home. At the same time, the value of developing web-based lessons was evident. However, the challenges of developing in-house web applications are many: how to transfer software to the students? How to make sure it is compatible with a wide array of computers and operating systems? How to strike a balance between creating a well-developed lesson plan and writing the actual code?

I spent the Spring semester of 2022 at LIGO Livingston SEC as an outreach fellow. I was well-versed in the Python programming language for my research, and I soon encountered Streamlit, an open-source framework for easy web-deployment of python code. Streamlit had been used previously within the LIGO education and public outreach (EPO) group to create a webpage [1] where users could easily visualise public data displaying the Gravitational-wave events detected by LIGO-Virgo so far.

With the goal of using the fundamentals of gravitational waves to teach high-school physics concepts of oscillations and waves, I experimented with the Streamlit interface and found it to be very easy to work with. I wanted to explain how a gravitational waveform recorded by our detectors is linked with the picture of two black holes spiralling into one another and colliding. The way these black holes move leads to interesting dynamics seen as changes in the frequency and amplitude of waves, which in turn can be used to teach these concepts. Streamlit enables making interactive plots where wave parameters can be modified by the user, and can even be played out as sound. At the end of the lesson, having learned different features of a gravitational wave, students can "make their own gravitational wave" by selecting masses of black holes. There is even a game at the end where students try to figure out which two black holes emit a particular waveform corresponding to one of the actual events detected by LIGO-Virgo.

Our new app [2] is cloud-based and hosted on the Streamlit server, which makes it possible for anyone to access it. There is no setup time and requirement involved for teachers. The lessons themselves can be either self-guided or conducted in classroom groups. All in all, Streamlit makes it possible for creating a free, easy to deploy, interactive online classroom lesson to teach the simple physics of oscillations and waves by connecting it to the frontiers of gravitational wave research.

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Contemporary Topics, Innovative Classrooms: Gravitational Waves and Dark Matter – Leveraging Astrophysics Research Collaboratives to Expand Physics

Speaker: Jackie Bondell and Ian Dewey, OzGrav/CDMPP, Australia

We introduce two initiatives led by Australian Centres of Excellence (CoEs) to create innovative lessons and professional development activities introducing curriculum-aligned contemporary Astrophysics concepts. The CoE for gravitational wave discovery developed extended projects aligned with senior physics curricula for students to do hands-on depth study of black hole mergers using interferometers and Python coding. The CoE for dark matter particle physics designed longitudinal partner programs in which schools have regular incursions and curriculum-aligned lessons related to the nature of science and the science of detecting the unseen, focusing on underserved schools. Both groups collaborate with science education researchers to study the efficacy of these school engagement initiatives.

Talk link: https://youtu.be/_yk_w-Wskyo

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Can we find space in the curriculum for contemporary physics and astronomy topics? How can we do this while providing teachers with the resources and professional development to use in an ongoing capacity? And what are scientists and research collaboratives doing to support education initiatives? We introduce and begin to explore these topics in this talk and invite attendees to access our resources for their own use in education. Specifically, we will introduce the Dark Matter Partner Schools Programs and the Gravitational Waves Depth Study.

Who are we?: We are a group of educators, science communicators, and researchers with the goal of providing contemporary Physics and Astronomy education opportunities to a diverse cross-section of students.

Our work comes under two Australian research collaboratives: the ARC Centre of Excellence for Dark Matter Particle Physics (CDM) and the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav). These groups are supported by the Australian Research Council. Jackie Bondell is the Education and Outreach Coordinator for both centres.

Carlos Lopez is the former principal of Stawell Secondary College, a government school in regional Victoria. Stawell is where the Southern Hemisphere's first underground dark matter detection lab is being built. He has been instrumental in liaising with CDM to support the pilot of the Dark Matter Partner Schools program.

A cohort of OzGrav scientists has contributed to the Gravitational Waves Depth Study content. These include Maddy Parks, Kendall Jenner, Zachary Holmes, Dr Dan Brown, and A/Prof Paul

Lasky. Ian Dewey is a Physics Teacher who has been a key driver to develop and drive the use of these Gravitational Wave activities in South Australian schools.

What are we doing?: OzGrav and CDM both have Education and Outreach portfolios. The goals of these are to bridge the research with the general public, with a focus on engaging teachers and students with exciting contemporary Physics programs. This talk focuses on two of these programs: CDM's Regional Partner Schools Program and OzGrav's Gravitational Wave Depth Study.

CDM's Regional Partner Schools Program builds multi-year collaborations with regional and rural schools to collaborate with teachers on delivering lessons that incorporate topics that align with Dark Matter science and the curriculum. The program provides multiple touchpoints over the course of many years with the goal of creating better pipelines into STEM for students from underserved areas.

OzGrav's Gravitational Wave Depth Study provides late secondary students to investigate gravitational wave (GW) physics in the context of the Physics study design. This includes modules using tabletop interferometers to understand GW detectors and a coding module to analyse GW signals from real LIGO data. This program was led by high school teacher Ian Dewey collaborating with OzGrav researchers and will be scaled to make it available to more educators.

Why these collaborations?: These programs aim to bring exciting new contexts to science education by connecting contemporary research and scientists with teachers and students. They particularly aim to improve pathways into tertiary STEM for a large cross-section of students while providing resources to support teachers in incorporating new content into their classrooms. We specifically focus when possible to engage with schools that are geographically distant from the metro centres as accessibility to many STEM opportunities is hampered by geography.

Project-Based Learning on Exoplanetary Explorations

Speaker: Chen Cao, Shandong University, Shandong Astronomical Society, China

Collaborators: Dongyang Gao (Shandong University, Nanjing University), Nan Song (China Science and Technology Museum), Dayong Ren (Shandong University)

In this contribution, we will discuss how to use observational facilities and real data of exoplanets (transits, radial velocities, transmission spectra, etc.) to make project based learning for high school & undergraduate students. Our research projects on exoplanet detection, characterisation, formation & evolution and habitability, allow students to form advisor led teams, for interactively learning exoplanetary sciences, scheduling observations, obtaining & reducing the data, making analysis and having discussions. Project based learning will engage students in solving problems, answering questions and team working. As a result, they can develop deep content knowledge as well as creativity, critical thinking, collaboration, and communication skills.

Talk link: https://youtu.be/V40c58pyy0U

In this contribution, we present our initial project-based learning (PBL in short) program on cutting-edge exoplanetary explorations. Since 1990s, advances in science and technology have enabled us to detect planetary systems orbiting around other stars, called exoplanets. Using only three decades, we have found over 5100 exoplanets around 3800+ exoworlds, it is now the forefront field in modern astronomy & astrophysics, we are on the "Pathways to Habitable Worlds" (Astro2020). It is relatively "new/innovative" in astronomy and has many challenging problems/questions, so should be good as a PBL testbed. Project-based learning (PBL) is a student-centered pedagogy that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge and develop success skills as well as: critical thinking, collaboration, creativity, and communication skills, through active exploration of real-world challenges and problems.

There are three steps (phases) for our PBL-exoplanets program: Phase I. scientific popularisation program on exoplanets discoveries; Phase II. observational system design and improvements for exoplanets studies; Phase III. (small) research topics on exoplanetary sciences.

During phase one, students should learn basic knowledge of our solar system and exoplanets, by reading astronomical textbooks and papers, also by web-searching. This student-centered learning activity is focused on planet formation, exoplanet detection & characterisation, and their habitability (atmosphere). This is accompanied by group discussions between students, teachers, and experts. Finally, the students should organise outreach and education activities for other students and public, these "artifacts" include: writing introductory articles, making short videos, and giving oral talks on exoplanets. Also these outreach activities can be used in IAU's NameExoWorlds 2022 campaign.

In phase two, students will start to familiar with telescopes and try to schedule their own exoplanet observations. Also, they must learn and practice on data reduction and analysis. Particularly, they should focus on problems like how to make good and efficient photometric and spectroscopic observational strategies, and how to improve the precisions, for example for reference photometry in exoplanets transit studies. Finally in this step, students should write observing proposals and technical testing reports, give presentations and make discussions. Our undergraduate and high school students have already made some observations & studies on exoplanets' transits using the 1m, 30cm, 60cm telescopes in our Weihai Observatory of Shandong university (WHO [1]). We got high-quality transit light curves and analyse the planetary parameters, some results were published in peer-reviewed articles (Zhang+2011, AcASn [2]).

In phase three, students can select and do some small but interesting research projects (topics) on exoplanets, this includes (but not limited to): participating in citizen science projects like Planet Hunters – TESS, performing transit and follow-up observations on exoplanets and candidates, make statistical analysis on exoplanetary and their host stars' properties, and study exoplanets' habitability by analysing their atmospheres using transmission spectroscopy, etc. Students will write their final research reports and articles, some excellent ones can submit to refereed journals. Also, they must present their results and findings to other students, teachers, experts, and the general public, to get feedback and evaluations. Their achievements can also attend China Adolescents Science & Technology Innovation Contest (for high schools) or Chinese undergraduate Astronomical Innovation Contest etc., this will be a great stimulation for our PBL-exoplanets program.

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Meet the IAU Astronomers!

Speaker: Suzana Filipecki Martins, Office of Astronomy Outreach, Japan

The “Meet the IAU Astronomers!” programme connects teachers, informal educators and amateur astronomer groups with IAU-members for meet-up (events) where professional astronomers have the chance to share their research, the importance of astronomy for society, and why following astronomy as a career is a viable and rewarding choice. The “Meet the IAU Astronomers!” programme goals is to “facilitate international communication through exchanges” and “encourage communication of science and critical thinking through IAU member public engagement”. A relaunch in spring 2022 was set to align the programme objectives and event structure with new evaluation instruments and to provide astronomers and organisers with tools that allow them to deliver inclusive events. Presented in comprehensive handbooks, the proposed structure and methodology widen the scope of the events and aim to facilitate events that strive to create lasting personal and social impact on the communities, participants and the astronomers themselves. The handbooks also encourage astronomers to consciously incorporate inclusive outreach practices and strategies that will encourage critical thinking, for example, by including opportunities for participants to identify, analyse, and evaluate the content shared. In this contribution, we introduce the programme and describe best practices gathered from other projects, such as STEM Ambassadors, that reflect inclusive practices and inform the “Meet the IAU Astronomers!” programme.

Talk link: https://youtu.be/zKqp5xIvN7Q

The “Meet the IAU Astronomers!” programme connects teachers, amateur astronomers, and informal educators with professional astronomers who are members of the International Astronomical Union (IAU) for virtual or in-person events. Through these events, the IAU members speak with children, adults, and other members of the public on astronomical research topics, the importance of astronomy for society, and choosing astronomy as a career. “Meet the IAU Astronomers!” programme is a variation of a tried and tested STEM outreach activity commonly known as STEM Ambassadors. From a learner perspective, programmes such as “Meet the IAU Astronomers!” “support learning by helping young people to understand real-world applications of science, they illuminate STEM careers through careers talks and links with the world of work, and they raise aspirations, demonstrating to students the wide range of people who pursue a future in STEM (https://www.stem.org.uk/sites/default/files/pages/downloads/STEM%20Ambassadors%20Report%2021_06%20FINAL.pdf).

At the same time, the programme aligns with IAU’s Goal 4 “The IAU engages the public in astronomy through access to astronomical information and communication of the science of astronomy", and OAO's strategic action: "Encourage communication of science and critical thinking through IAU member public engagement, professional-amateur, and citizen science activities"(IAU Strategic Plan 2020-2030 - https://www.iau.org/static/administration/about/strategic_plan/strategicplan-2020-2030.pdf).

"Meet the IAU Astronomers!" (https://www.iau.org/public/meettheiauastronomers/) objectives are to:

- Communicate the science of and current research in astronomy.
- Stimulate critical thinking.
- Change perceptions, attitudes, behaviours, social norms and stereotypes towards astronomers, showing that astronomy is a collaborative science made by a diverse group of individuals.
- Stimulate the uptake of astronomy as a career choice, especially for girls and children from underserved communities.
- Engage astronomers with wider communities and help build a perception of how their work contributes to making our planet more peaceful, sustainable and fair.
- Encourage the participation of IAU members in public engagement and collaborations.

After its first years of implementation, the programme was relaunched in the Spring of 2022. The OAO put in place new tools for astronomers and event organises with the aim of better aligning the programme objectives and its implementation. Tools included:

- Guidebooks for Astronomers and organisers that include information on how to prepare for the event, how to make the event more inclusive, and how to stimulate critical thinking.
- A set structure for the event.
- Surveys that help the OAO understand if the project is responding to its goals and objectives and if they are being implemented in the best way possible.

As of November 2022, 203 astronomers have registered to take part in the programme. The registered astronomers come from 52 countries, primarily from the United States, India, Spain, the United Kingdom and Germany, who can deliver events in 40 languages. The IAU Office for Astronomy Outreach (OAO) has received 42 event requests from 28 countries, mainly Pakistan, Mexico, Albania, Argentina, and Peru.

Resources:

- Other STEM Ambassadors programmes: STEM Ambassadors (UK): https://www.stem.org.uk/stem-ambassadors; Fureai Astronomy: https://prc.nao.ac.jp/delivery/; Portal to the Public Network: https://popnet.instituteforlearninginnovation.org/about/

The Dutch Black Hole Consortium Education Programme: A Cutting-Edge Interdisciplinary Research Collaboration with Education at its Heart

Speaker: Joanna Holt (On behalf of the Dutch Black Hole Consortium), Smart Education Lab, Amsterdam University of Applied Sciences and Netherlands Research School for Astronomy (NOVA), the Netherlands

The Dutch Black Hole Consortium brings together cutting-edge research from subjects as diverse as astronomy, engineering, and geology to further our understanding of black holes and gravitational waves. At its heart is an ambitious educational project to bring the results into both classrooms and informal learning settings. For primary level, lessons are being created using innovative smart education techniques and research will focus on how to support learners to think scientifically. At secondary level, the focus lies with teacher education; trainee physics teachers will be able to experience real scientific research to inspire and improve their classroom practises. The consortium is also developing a large citizen science project and exhibits for two science museums/centres.

Talk link: `https://youtu.be/QUPs-m0t0tI`

The Dutch Black Hole Consortium comprises a group of more than 30 scientists carrying out interdisciplinary research in the Netherlands. The collaboration is extremely broad including astronomers, theoretical physicists, engineers and telescope developers, geologists, seismologists and education and outreach specialists. Whilst at face value the topics sound unrelated, all are necessary to further our understanding of black holes.

Another crucial aspect that makes this collaboration unique is the emphasis on education and outreach. Whilst education and outreach is often an add-on in many projects, a third of the work effort and budget in the Dutch Black Hole Consortium is dedicated to disseminating black hole science to the wider public and educating and inspiring the next generation of scientists.

The Dutch Black Hole Consortium has funding initially for six years and officially started work in September 2021. More information about the consortium, its members, work-packages, meetings and regular updates on progress can be found on our website.

A brief overview of the work-packages

The astrophysics effort includes work related to black hole imaging and modelling and the progenitors of gravitational wave events, both from an observational and theoretical perspective (WP1-4). The consortium is also contributing to the Einstein Telescope (WP5,6), a new gravitational wave detector that will be built within the next decade. The consortium is developing new technologies required for the telescope design. One of the possible sites is in the very

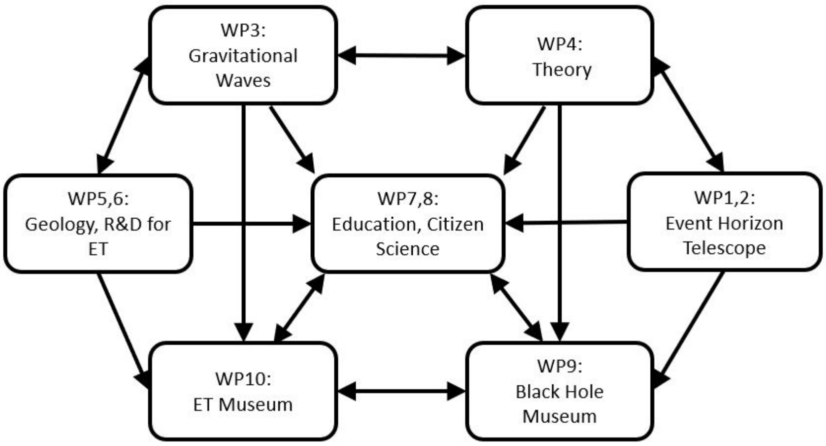

Figure 1: The Dutch Black Hole Consortium

south of the Netherlands, straddling the border with Belgium, however the geology of the area is currently not well understood. The consortium is therefore performing a detailed geological survey of the potential site.

The final 4 work-packages (WP7-10) are focused on education and outreach and will draw on and promote the other work-packages (Fig. 1). The consortium is creating new content for the interactive science centre Discovery Museum in Kerkrade and the Boerhaave Science Museum in Leiden. There will also be a large citizen science project related to the data from the BlackGEM telescope, whose main scientific goal is to identify optical counterparts of gravitational wave events. The test version is expected to ready in early 2023 with a public version later in the year. Alongside these activities is an extensive formal education package (see below).

Education at primary and secondary level

The formal education package includes three main goals. Figure 2 highlights how these goals are related to each other and the broader consortium:

1. A lesson package for upper primary level (10-12 yrs) to stimulate scientific thinking through hands-on – minds-on learning with an interactive digital tool.

2. Research internships for trainee physics teachers to give them experience of real scientific research to help them convey what it really means to be a scientist in the classroom.

3. A dedicated PhD project to research the impact of the educational programmes in both formal and informal settings. This research will provide important information for discussions at high level aimed at improving the visibility of cutting-edge science in school curricula and lesson materials in general.

Lessons for primary schools

The primary lessons will tackle relevant primary science goals and will assist teachers to teach science and support learners in developing scientific thinking skills. The lessons also aim to inspire children to be scientists of the future. The Dutch Black Hole Consortium provides an exciting context of cutting-edge science and technology.

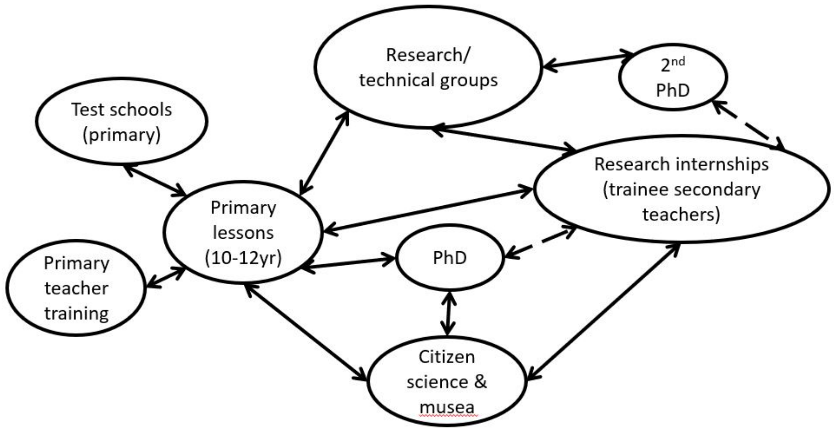

Figure 2: Formal education at primary and secondary level

In each lesson, a science concept will be combined with a scientific thinking skill. The science concepts will be drawn from the Dutch curriculum for upper primary. Whilst black holes and other topics from the consortium do not appear specifically in the primary curriculum, science concepts relating to them do, such as gravity and light. To address scientific thinking, each lesson will focus on one of the seven cross-cutting concepts[1] such as cause-and-effect reasoning, patterns or thinking in systems. Lessons will consist of short practical activities interspersed with an interactive concept diagram in a digital tool. Learners can, for the most part, work independently in the tool and receive automated feedback and interaction to stimulate the thought process. The lessons will build on the existing project Minds-On. Lessons will be evaluates using a suite of tools including pre- and post-tests, teacher and learner questionnaires and click-data from the tool.

Black holes in primary schools

Black holes do not appear in the primary school science curriculum, so why should we want to bring topics such as black holes into the primary classroom? It is now well known that astronomy topics are perceived as some of the most interesting science topics by both boys and girls though projects such as the Rose project. Practical experience of the Netherlands Research School for Astronomy (NOVA) Mobile Planetarium project also show that even the youngest children have heard about black holes and are curious to learn about these exotic objects.

Summary: The Dutch Black Hole Consortium is an interdisciplinary collaboration of scientists from the fields of astronomy, theoretical physics, technology, and earth sciences in which education lies at the heart.

[1]National Research Council (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee Conceptual Framework New K-12 Science Education Standards.

Using Authentic Exoplanet Data to Promote Active Learning of Physics and Mathematics in Schools

Speaker: Carla Hernández, 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), Chile

Collaborators: Fernanda Alarcón (USACH), Ignacia Benito (USACH), Irma Fuentes (YEMS) & Sebastián Pérez (USACH, CIRAS, YEMS)

Chile benefits from a favourable position to develop astronomy; however, teacher training in the area is low, and there are few opportunities for students to learn about frontier research. To address this challenge, we built a group of astrophysicists, science education specialists, and high school teachers to co-construct active-learning activities using exoplanet data for physics and mathematics classes. Our team worked with almost a hundred students from three schools to pilot our activities. The results show that teaching frontier astrophysics in school classrooms is possible and promotes students' interest in science. We believe this project contributes to bridging the gap between astrophysics research and teaching science in school.

Talk link: https://youtu.be/V9-XxgogS9I

Living in a privileged geographical area for astronomical observation allows this line of research to be one of Chile's most relevant areas of knowledge [1]. However, a review of the national educational curriculum reveals little astronomy content taught at the school level [2]. The limited curricula and the lack of updated content reflecting the latest findings in frontier astronomy represent an obstacle for students to learn about the diversity of astronomical phenomena and, particularly, what is investigated in Chile.

To address this challenge, we built a professional learning community [3] composed of astrophysicists, science education researchers, and high school teachers to co-construct active learning activities using exoplanet data for physics and mathematics classes. We implemented activities for more than 100 Chilean students aged 14 and 15.

We used the Open Exoplanet Catalogue to select information on the radius, mass, period, and semi-major axis, among others, for 800 exoplanets. The data were delivered to the students in Excel's .xls spreadsheet format in class. Students used them to learn about graphs, record populations in double-entry tables, build scatter plots, and draw trend lines, among other mathematics topics. In physics classes, the data was used to study Kepler's Laws and to establish comparisons between variables following the objectives of the national curriculum. In addition, using the NASA Eyes on Exoplanets platform, they could visualise different systems and access more information about the host stars, detection techniques, and habitable zone.

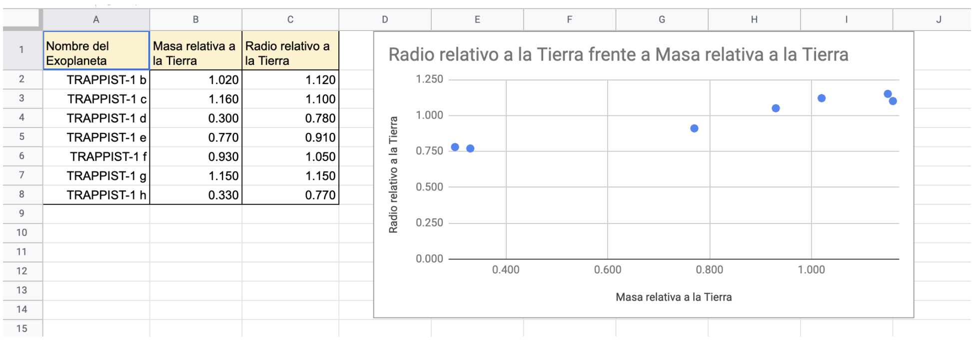

Figure 1: Graph made by a group of students on correlations and linear trend, with data from the Trappist-1 planetary system.

Figure 1 shows the graph obtained by the students when analysing mass and radius data (relative to the Earth) for the Trappist-1 system. Since each group of students worked with data from a different system, comparing results and formulating joint conclusions were encouraged. The process was repeated using data from our Solar System and a table with information on 800 exoplanets. Subsequently, their results were compared with a graph that we provided to the teacher for the more than 5000 exoplanets that had been detected to date (Fig. 2).

At the end of each activity, students were encouraged to formulate questions for the researchers based on the work done in class. We could identify questions formulated in categories [4], as shown in Table 1.

At an exploratory level, participants were asked about their perception of scientific activity and whether it had changed due to the work done in class. Some of the answers obtained were the following:
E2_3, "Yes, because I was able to know an area of science more in-depth than I knew."
E2_7, "Yes, in the aspect of knowledge and data processing, since these disciplines are very much related to mathematics and statistics."
E2_27, "Yes, because I thought that science was only one method, but with the work, I learned that science had several topics."
The answers obtained concerning perception suggest that the work carried out using actual data from frontier astrophysics favours the motivation and interest of students in astronomy and scientific work in general.

Based on the results, we consider that the possibilities and scope of this project are extensive. On the one hand, we realise that bridging the gap between research and the classroom is possible. Doing so implies collaborative work based on horizontality and mutual respect for

Table 1: Examples of questions asked by students at the end of the activities.

Category	Sample student question
Nature of Science	What is the benefit of discovering an extrasolar planet?
Scientific Knowledge	How likely is it that a planet like Earth exists? Are there habitable planets nearby?
Scientific Activity	What instruments and methods do you use to obtain data from planets?
Scientific Career	Why did you want to study astronomy? Is it fun to find a new world?

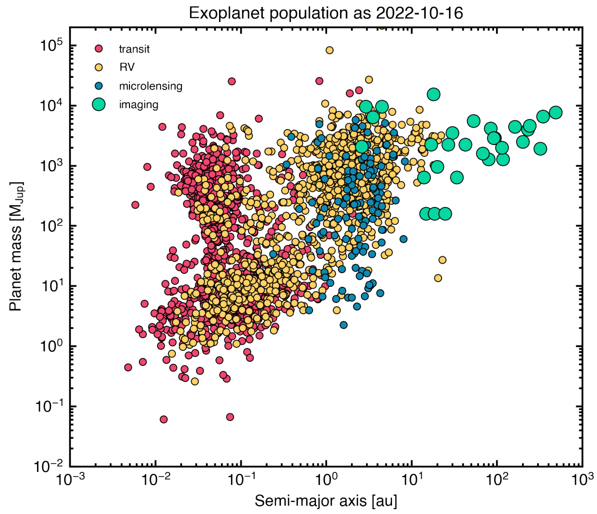

Figure 2: Plot showing the mass of exoplanets versus the size of their orbit. The colours of each data cloud indicate the method by which the exoplanets were detected. Plot prepared by Sebastián Pérez for teachers (in Spanish), from the data available in the Open Exoplanet Catalogue.

the training of teachers and scientists. We note that a limitation of this work is its reliance on technology. In some locations of our country, lack of technology access may hinder data use in the classroom. However, we propose alternatives for its use in the guidelines for teachers that accompany the activities.

As work prospects, we will also conduct a free training workshop for Chilean teachers who want to implement these proposals in their classrooms, with the support of the IAU-OAE Teacher Training Pilot Program. Also, this year we are part of the Global Sky Partner. We were assigned hours of astronomical observation at Las Cumbres Observatory to obtain light curves of the nova eruptions and develop activities to teach exponential and logarithmic functions. In addition, we will work with an amateur observatory in Chile to obtain actual data on southern star spectra. This way, we will add a chemistry teacher to create new activities. The designed activities will be published for open use through the `www.ciras.cl` website starting in 2023.

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Incorporating Astronomy Research into the Classroom

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

As part of my work with the Faulkes Telescope Project, I present examples of work done with students in various fields of astronomy research. Examples include studies of black hole X-ray binaries, open clusters, supernovae and exoplanets. In many cases, students follow the entire scientific process from target selection to observation to analysis and conclusions/reflection. While allowing students to learn, and be inspired by, astronomy, they are also able to practice implement transferable skills though the medium of astronomy. These skills are particularly prevalent in the fields of IT and maths.

Talk link: `https://youtu.be/If0_Rm1mowk`

The Faulkes Telescope Project provides telescope time free-of-charge on the Las Cumbres Observatory (LCO) robotic telescope network. In addition to telescope access, we provide resources on finding suitable targets, image processing and photometry. Here, I discuss some activities I have helped to design in the areas of exoplanets (especially transiting systems) and in black hole binary systems.

One of my exoplanet activities is part of a set of three inquiry-based activities produced using real astronomical data in the subject areas of exoplanets, supernovae and open clusters. In addition to this, I have been working since early 2021 with a group of astronomy educators and students in a project called GWAM (Gee Whizz Astronomy Modelling). This project has allowed us to collect several sample datasets on exoplanet transits as well as providing us with invaluable insight from our students into what properties make a suitable target for imaging with the LCO network.

Working with Dr. Rosa Doran (NUCLIO, Portugal) and capitalising on my research area of X-ray Binaries (XRB; binary systems comprising a compact object with a 'normal' star), I have also helped to develop an activity called Black Holes In My School. This involves the creation of a light-curve of a short orbital period XRB and via photometry and Kepler's Laws. It allows students to explore the mass of the compact object, which could only a neutron star or black hole.

Each of these activities harnesses the enthusiasm that students have in astronomy in general and in particular, in these areas which are still at the forefront of research. They include broader STEM skills such as graph plotting, uncertainties, logarithms and cover areas that are common to many physics curriculums across the world.

Sparking Imaginations with Black Hole Images

Speaker: Chi-kwan Chan, Steward Observatory and the Department of Astronomy, University of Arizona, USA

Black holes are regions of extremely distorted spacetime that not even light can escape. As predictions of Einstein's general theory of relativity a hundred years ago, black holes have captured the public's attention for many years and have influenced science friction, movie, music, and pop cultures. When we released the first ever images of black holes at the center of M87 in 2019 and our Milky Way earlier this year, students all across the world learned that black holes are real, and learned that through science, we can make predictions that were once beyond our imaginations. Using this opportunity, the EHT engages with students at all levels to promote astronomy, scientific thinkings, and mathematical reasonings. In this contribution, I will share the methods and lesson-learned from the EHT.

Talk link: https://youtu.be/4jP4UkQ6JAI

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Black holes are regions of extremely distorted spacetime that not even light can escape. As predictions of Einstein's general theory of relativity a hundred years ago, black holes have captured the public's attention for many years and have influenced science fiction, movie, music, and pop cultures.

The Event Horizon Telescope (EHT) project aimed to capture the first images of a black hole. When we released the first ever images of black holes at the center of M87 in 2019 and our Milky Way earlier this year, students across the world learned that black holes are real, and learned that through science, we can make predictions that were once beyond our imaginations. Using this opportunity, the NSF-funded Black Hole Partnerships for International Research and Education (PIRE) project engages with students at all levels to promote astronomy, scientific thinking, and mathematical reasoning.

We worked with different educators and passionate people on developing different education materials. With worked with an education major student who happened to enjoy astronomy to develop class modules for elementary and middle school students. These materials are short in-class modules with activities to engage young students. We describe basic concept such as force, speed of light, and black holes, but did not go into too much details and math. We learned that elementary and middle school education is completely different from University education. We heavily rely on our education major student to select content at the right level to match the students' ability.

We worked with Zoom to create the Zoom Classrooms "Chasing Black Hole" to provide additional science educations for high school students. This was set up before the pandemic so zoom was a new technology for everyone. For each classroom, two scientists from the EHT and one host from Zoom would connect to hundreds of classrooms across the US, where the EHT scientists provided a high-school level introduction to gravity and black holes. We also provided additional materials to teachers so they can set up activities and exercise to engage with the students. The exercise uses simple math to help the students understand the material they learn from the Zoom Classrooms. For this work, partnerships with high school teachers and technology company such as Zoom are essential. While material selection is less difficult compared to elementary and middle school, engaging high school students and exciting them in science is non-trivial. New technology itself is an interesting way to draw the students' attention. And at the end we need teachers to provide the follow up activities to ensure the students were able to learn something meaningful.

At University level, although there are astronomy courses (and we have helped creating education modules), to engage students who normally would not take a science course, we worked with the University outreach office to create additional activities. We drew an Einstein with chalk and put it on campus during new student visit. Hundreds of students and their parents walked by our chalk art, imagined what is on the other side of a black hole, wrote down their answers, and took pictures with the art. I personally answer questions raised by almost hundred people, and motivate about ten art students to take introductory science courses.

In short, the public is curious about black holes. Using it as a motivation, the Black Hole PIRE project successful engaged with the students at all level and public in black hole research. We collaborate with our colleagues and external partners to develop education materials at all levels, from elementary and middle school, to high school and even Universities level. We learned that 1) it is ok to leave out the details, 2) creativity is important, and 3) it is absolutely essential to work with educators and people who care about education.

Engaging Students and Teachers with the Exciting New Field of Gravitational-Wave Astronomy

Speaker: Martin Hendry, SUPA, School of Physics and Astronomy, University of Glasgow, UK

In just a few years the detection of gravitational waves has progressed from global breakthrough to almost routine occurrence. This exciting, young field offers excellent opportunities to engage and inspire STEM students and teachers through its combination of more advanced science topics which enjoy widespread popularity (black holes, general relativity, quantum physics) and more fundamental concepts (in mechanics, gas physics, lasers and materials) at the core of high school, college and university science and engineering courses. Here I highlight some of the approaches, adopted by the LIGO Virgo KAGRA Collaborations and the LISA Consortium, to convey the exciting science of gravitational-wave astronomy to STEM students and teachers across the globe.

Talk link: https://youtu.be/o3GRe2vEWyc

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The discovery of gravitational waves (GWs), in 2015, marked the beginning of an exciting, new era in astrophysics that has opened a completely new window on the universe. In just over seven years since then, the LIGO, Virgo and now KAGRA (LVK) collaborations have made almost 100 confirmed detections of GW events, from collisions of pairs of black holes, neutron stars and black hole-neutron star systems, with the most recent catalogue of these events published in November 2021.

Long before the first GW detection, the LIGO Scientific Collaboration (LSC) had already been firmly committed to a programme of education and public outreach (EPO) – with the LSC EPO group first established in 2008 and a White Paper describing the Collaboration's activities written to guide the development of the group. The latest version of that White Paper, now evolved to become an inclusive document that sets out the strategic mission and collective EPO goals of the LVK Collaborations, reaffirms our commitment to harness the excitement generated by GW research to inspire and educate students and the general public in astronomy and fundamental science. We believe that the opportunity to discover the beauty of the cosmos should not be limited by age, culture or abode.

The EPO activities of the collaborations span a wide range of categories, and include:

- active visitor programmes at the various detector sites around the world;
- outreach in formal and higher education, particularly focused on providing online resources to support students and educators who wish to access and analyse GW data;

- informal education activities to multiple audiences – including the creation and curation of visual and audio multimedia, social media engagement across multiple platforms, educational games and apps, exhibitions on GW science and public lectures and discussions;
- outreach to other scientists, funding bodies, politicians and other stakeholders.

In this contribution I highlight a few examples of these activities that are particularly targeted at high school students and educators. Although my talk draws upon many years of leadership of LSC EPO efforts, I am not presenting formally on behalf of the LVK and instead am merely seeking to offer some brief, personal perspectives. I apologise in advance for any specific activities or contributions that I have overlooked due to lack of time/space. The interested reader can, of course, find out much more about LVK outreach programmes by following the links provided below.

Some Key EPO Resources for students and teachers
The essential launch-off points for students and educators wishing to learn more about GWs are our Collaboration websites (`https://www.ligo.org/`, `https://www.virgo-gw.eu/`, `https://gwcenter.icrr.u-tokyo.ac.jp/en/`). At `www.ligo.org` there is a section with resources about all of our main discovery announcements that includes animations, skymaps, visualisations, infographics and factsheets. You will also find links to our LIGO Magazine which has been produced twice yearly since 2012 and contains lots of articles written at the level of a high school audience; these describe not just the science we have learned but also the global family of scientists behind the discoveries.

Another flagship EPO resource is our science summaries: non-technical articles that accompany every one of our Collaboration papers and are written by the same scientists who lead the writing of the papers themselves. Again, they are aimed at a general audience: high School students, teachers, journalists as well as other scientists. We always seek to relate the content of our science summaries to the science topics that high school students are exploring in their classes, so they are an excellent tool for stimulating classroom discussion, supporting self-study or enhancing skills in science communication. We have produced over 160 summaries to date, and they have been translated into more than 20 languages.

The Gravitational-Wave Open Science Center
Our EPO team also helps to support and promote the GW Open Science Center (GWSOC). Here you can access actual data from previous LVK Observing Runs and explore tutorials and programming tools to help you analyse our GW detections for yourself. In recent years the LVK Collaboration, led by the GWOSC team, have hosted several online and in-person workshops that provide training in GW data analysis; these have been attend by thousands of participants and the most recent workshop (held in May 2022) is still available to be taken as an online self-directed course. Whilst these workshops have been very popular and attracted participants with very little prior knowledge or expertise, a key future EPO goal is to create a new version of the GWOSC tutorials that is tailored for high-school students and teachers – without requiring any prior programming experience.

As a first step towards such provision, our LSC Caltech colleague and GWOSC lead, Jonah Kanner, has already created a “learning path” on the GWOSC homepage that complements the existing GWOSC tools and workshop materials. The learning comprises two introductory videos and a simple, interactive tool (created by our LSC Cardiff colleague Chris North) to learn about the basic ideas of waveform fitting and matched filtering. Students can then dive a little deeper into the science behind the waveforms themselves and what they can tell us – drawing heavily on analogies with musical frequencies and harmonics – before applying this knowledge to find a secret sound hidden in noisy data: directly analogous to the actual process of analysing GW signals. Finally, students can use a simple graphical interface to plot and explore some real GW data, with a list of follow-up resources also available for further investigation.

In short, there are excellent resources available to help high school students and teachers learn about our GW discoveries – including interactive tools to let them explore the data directly. There are also multiple ways for students to reach out to the GW community to ask questions, such as our LVK discussion forum ask.igwn.org, our dedicated email address question[at]ligo[dot]org and our various social media platforms (Twitter: @ligo, @ego-virgo, @KAGRA_PR, @LIGOIndia; Facebook: @LigoScientificCollaboration, @EGOVirgoCollaboration, @kagra.pr, @LIGOIndia; Instagram: @ligo_virgo, @ligoindia).

So with our network of detectors set to begin the fourth LVK observing run in spring 2023, with the prospect of even higher detection rates and lots more discoveries, there has never been a better time to explore the exciting new field of GW astronomy.

Space Scoop

Speaker: Florian Seitz, Haus der Astronomie, Heidelberg, Germany

"Bringing news from across the universe to kids all around the world" is the claim of the Space Scoop project. Current astronomy press releases and publications are edited and presented especially for children. Interested children get insights in what is going on in astronomy right now. New Space Scoops are presented regularly. A translator network translates these Space Scoops in different languages.

Talk link: https://youtu.be/1Zfiivji7zc

Space Scoops (www.spacescoop.org) bring the latest astronomical research into the classroom. The short texts cover exciting astronomical topics in easy-to-understand language.

The Space Scoop partners are astronomical research institutions that send their press releases to Space Scoop. Some of these press releases are then edited for children and young people and published on the homepage. The design and operation of the homepage is adapted to the user group.

The texts are kept short, simple, and understandable. The tone is playful but serious enough. The Space Scoops are translated into over 30 languages by a network of volunteer translators. This way, many children in this world have access to fascinating new insights in astronomy.

Amateur Astronomer Magazine Provides Chinese Students with Cutting-Edge Science Contents

Presenter: Feng Chong, Beijing Planetarium, China

'Amateur Astronomer' magazine is the earliest and most influential astronomical science journal in China. The magazine has a monthly circulation of 16,000 copies, and the readers are young students. The magazine can be fast, accurate, and stable in terms of response speed, quality of content and topic continuity. First, the editors have been closely following the frontiers, keeping close contact with astronomers. Second, the professionalism and accuracy of the presented content is ensured by interviewing with astronomers. Third, many hot issues can be presented from the time they are proposed to that are confirmed. Finally, the magazine added current affairs to the annual Chinese National Astronomy Olympiad to guide students to pay attention to the progress of astronomical research.

Poster link: https://astro4edu.org/siw/p89

'Amateur Astronomer' was founded in 1958, and it is the earliest and most influential astronomical science magazine in China. The magazine mainly introduces the basic knowledge of astronomy, tracks the hot spots of astronomy, and cultivates the observation practice ability of young astronomy enthusiasts. The magazine has a monthly circulation of 16,000 copies, and the readers of the magazine are mainly young students in school.

For the frontier achievements of astronomy, the magazine can quickly respond, accurately interpret, and keep an eye on the topic. Based on actual data, the magazine had annual introductory articles in the field of black hole shadows, gravitational waves and exoplanets during recent years. Especially when the black hole shadow news first appeared, it was immediately featured in the magazine. In addition, the magazine added current affairs to the annual Chinese National Astronomy Olympiad held for school students to guide them to pay attention to the progress of astronomical research forwardly.

Taking the black hole shadow as an example, the magazine introduces both the basic background knowledge and the latest photos. From the initial prediction of the different black hole shadow forms that may be seen by the Event Horizon Telescope, to the first release of a photo of the black hole at the center of M87 in April 2019, to the release of an image of the M87 black hole in polarised light in March 2021, to the recent release of a photo of the black hole in Sgr A* at the center of the Milky Way in May 2022, the magazine has continued to give the fastest science interpretation. And the specific formats are varied, including cartoons, science pictures, and simplified articles on science to reduce reading difficulty and help students understand.

Taking the gravitational wave as an example, the magazine tracks the early theoretical studies of gravitational waves to the later actual observations of the signal. A complete history of the development of gravitational waves is presented for young readers. In addition to theoretical knowledge and actual observational progress, the magazine also introduces the scientific institutions conducting gravitational wave research, giving students a comprehensive understanding of this cutting-edge progress.

Taking the exoplanet as an example, the magazine starts with students' reading interests and combines distant celestial bodies with the familiar atmosphere, oceans and temperatures on Earth. Combining the latest astronomical knowledge with students' imagination, it helps them understand the wide variety of exoplanets. The magazine also publicises and promotes IAU's public-facing exoplanet naming programs. The event is a way to get students more interested in the topic of exoplanets and to learn more about the science involved. On the other hand, it also provided a place for teachers to exchange ideas, so that school teachers can also access more cutting-edge astronomical content.

Mimicking of Gravitational Lensing and Microlensing in a Classroom

Presenter: Jun Su and Jingcheng Zhu, Haian Senior School of Jiangsu Province, Jiangsu Province, China

When a point-like object passes between a background light source and an observer, the background illuminance fluctuates due to the gravitational microlensing effect. These objects are called massive astrophysical compact halo objects (MACHOs). In this project, an optical lens corresponding to a gravitational lens was printed using a 3D printer to demonstrate the images of an Einstein ring and a light source. Meanwhile, a process for searching for MACHOs and exoplanets was simulated based on the 3D printed lens, which could well present the total brightness change of the gravitational microlensing effect.

Poster link: https://astro4edu.org/siw/p90

Discussion summary

This session addressed the possibilities and strategies to bring cutting-edge science to the classroom and address topics such as gravitational waves, black hole shadows and exoplanets in a way that can be linked and ideally beneficiary to the curriculum. Due to the wide range and great importance of this topic, the session was split into two parts with a total of 11 talks and two posters. We thank the speakers for their inspiring contributions!

During the four different discussion sessions, it was repeatedly mentioned that breaking topics down into smaller units is key to make complex topics approachable by students. Looking at the curriculum will help to make a plan how to break things down, as the curriculum can provide pointers to what is known and what should be learned. But it will also depend on the look the teachers have: a mathematics teacher will look at it differently than a physics teacher as different aspects are important.

Breaking things down is also important when letting students use real data from telescopes. The educators are able to decide from which stage the data should be used: It can start with students taking their own raw data or prepared datasets that we know work, can be provided to the students. Providing a prepared data set, such as a catalogue rather than images, is possible also with a less stable internet connection. Either way, this data will look different than the images that we are used to from the news and we need to prepare students for the fact that the observations will not be a perfect graph just yet, but have bumps and glitches in them. Along this way, the students might also go on a different path with exploring the data than imagined by the scientist or teacher, and in an inquiry based approach we should not be afraid to let the students do so. The fact that images are not perfect, is often seen inspiring to students and interests them a lot, but the fact that not everything is complete yet, not every answer is there, also opens doors for them to think further. It also teaches students about the nature of science: it is evolving, and not perfect or finished.

The topic of cutting-edge science in the classroom is unique in the aspect that it is rapidly changing and thus (understandably) challenging for teachers to stay up to date. Therefore, text books can be outdated. It is recommended from several speakers that the teachers are provided with a handbook to be able to learn the necessary background information. Such a handbook can also include a lesson package for the teachers and should be structured in an interesting manner and that is accessible. The challenge is to find a middle-ground, with sufficient (but not too much) information given, ideally offering different levels of background for the more interested reader. Language is a barrier, as it takes time to translate new teaching concepts or materials into other languages, making access harder for teachers not fluent in English. Space Scoop is a project that provides cutting edge results in short texts, translated into many languages and written for students, in an appropriate level and this is a comfortable starting point of reading materials (also for foreign language classes).

Workshop and Community Discussions

astroEDU Workshop

Session organisers: Livia Giacomini (INAF, Italy), Giulio Mazzolo (Switzerland), Edward Gomez (LCO, UK), Gwen Sanderson (OAE Heidelberg), and Federica Duras (INAF, Italy)

Workshop summary

The objective of the “Let’s learn with astroEDU!” interactive workshop was to introduce astroEDU (https://astroedu.iau.org/en/) and to present the publication process of new educational activities to new potential authors, reviewers or collaborators. About 150 participants from more than 50 different countries attended the two sessions. More than 20 participants left their email to be contacted after the workshop.

Each session of the workshop started with a general presentation of astroEDU, its audience and the activities already published (approx. 30 min). The second part of the workshop, titled “How to transform an educational activity in an astroEDU online resource”, lasted about 1 hour and was more interactive. Participants were guided through two different case studies of activities already published (Make your own Sun! and Let’s play with powers of 10). They were invited to take part in the review and publication process by answering a set of questions both in the chat and via polls, describing their own point of view, and by joining the discussion. Finally, they were also invited to submit their own activities to astroEDU for publication.

We found the response of participants to be very positive and that workshops are very effective at introducing astroEDU to the community. To maximise the number of participants, we decided to limit the interaction to polls and questions in the chat, asking participants to keep their microphone muted. We think that repeating the workshop with smaller groups (less than 20 participants) would make the workshop more interactive.

Arabic-Speaking Community Discussion

Session organisers: El-Fady Morcos (Egypt), Magda Moheb (Egypt), Somaya Saad (Egypt), Hamid El Naimiy (UAE), Awni M. Khasawneh (Jordan), Mashhoor Al-Wardat (Jordan), Ahmed Chaalan (Lebanon), Ali Al-Edhari (Iraq), and Mohamad Alassiry (Syria)

Discussion summary

Within the framework of the expansion of Arab cooperation at all levels, the aim of this session was to extend the horizons of the Arab cooperation to include Astronomy Education in the Arab world and to exchange experiences in this field. We discussed the systems and curricula of astronomy education in Arabic-speaking countries and the role of the Arab cooperation in the areas of Astronomy Education, Development and Outreach. The main topics addressed were, Astronomy curricula in the Arab world between the reality and the hopeful; Suggestions about ways to expand the Astronomy Education for the pre-university stages; Teaching astronomy as part of the basic sciences, mathematics, physics, chemistry, engineering, and geography; the role of modern technologies in the development of astronomy education.

The session comprised of talks by speakers from different Arabic-speaking countries. The first speaker was Mashhoor A. Al-Wardat (NAEC) focused on the role of private and governmental educational institutions, planetariums, and bodies specialised in developing learning and teaching methods, especially interactive ones, in the horizons of space and astronomical sciences. We briefly discussed the role of each of these institutions, and present in detail the role of the University of Sharjah, represented by Sharjah Academy for Astronomy, Space Science and Technology (SAASST), in employing its scientific and technical competencies in developing the education sector. The talk also clarified that all specialised institutions in astronomy and space sciences in the country, in cooperation with the Ministry of Education, have contributed to the establishment of workshops to provide teachers with the necessary skills to teach these sciences. Manufacture of cubic satellites and launched several specialised professional diplomas, some of which were allocated for gifted school students and others for the distinguished in cooperation with the Sharjah Education Council, and several astronomical camps were set up to train students and teachers in a practical way.

As a result of all this over the past seven years, the number of those interested in these sciences increased, the number of students enrolled in the physics and aerospace engineering departments in universities increased, and several programs at the graduate level were launched in these disciplines in state universities.

The second speaker Ali Al-Edhari (NAEC, Iraq) presented the contents of the astronomy curriculum in Iraq for the initial (pre-university) stages. The speaker focused on the problems teachers face when they are teaching the astronomy content to the limit that some teachers skip teaching the astronomy part. The speaker mentioned that, there are no specialised school courses in astronomy. Instead, astronomy content can be found in science and physics public and private schools curriculum; General Science (years 1-6 of primary school) and Physics (years 7-12) of secondary and high school.

The experience of teaching astronomy at the undergraduate level and the draft school curricula for teaching astronomy in Lebanon was discussed by Jan Pierre Seghini (NAEC, Lebanon). The speaker highlighted the main weaknesses in curricula and method of teaching astronomy and suggested some solutions. With respect to Lebanon, the speaker mentioned that Astronomy is taught only as a special course in four private universities in Lebanon, not public universities, and there is only one university that offers a Master's program in astrophysics, and also one university to offers a doctorate program. Government schools do not have astronomy in the curriculum but some private schools have included geography and scientific curricula. A proposal has been submitted to the Ministry of Education to update the curriculum at three educational stages in cooperation with the Institute of Science and Development.

Awni Khasawneh (NAEC) and Dalal Ellalla (astronomy trainer) discussed the astronomical topics in the Jordanian school curriculum. In their talk they mentioned that education in Jordan is considered as one of the best education systems in the Arab world. Education plays a pivotal role in the life and culture of Jordanian society, which has lead to allocating 13% of the Jordanian government budget for 2022 to the education system. The speakers highlighted the role of the Jordanian Ministry of Education and Higher Education, the Arab Union for Astronomy and Space Sciences and other societies in supporting educational programs by organising events, activities, workshops, conferences, and astronomical camps. Many specialised astronomical courses are offered in the field of education such as the astronomy teacher course, and an astronomical skills course for teachers.

The last talk was by Abd El Fady Morcos (Deputy manager, OAE Center Egypt) about evaluation of astronomy curricula in Egypt and development mechanisms. The speaker mentioned the future plan, which is divided into six main themes, namely: teachers, curricula of different stages of education in Arabic, preparing astronomical material, student axis, surrounding Arab countries and popular, amateurs and astronomy associations. For the first theme, teacher training workshops (three courses) about teaching Astronomy have been organised in the past and will be repeated. An analytical study for the curricula of astronomy for the stages of pre-university stage was undertaken and efforts are being made to setup a parallel course to help students and teachers. Simple models of some astronomical devices have been prepared and social media sites containing astronomical information are developed. Students are encouraged to visit Helwan and Kottamia observatories and camp in Kottamia for an observing night. Astronomical books and booklets for student and the general public have been published. The main problems faced in Egypt are that the teachers do not have free time to attend training courses; the training programs are not formalised with the ministry of education; administrative contact in the ministry of education is difficult; consultants and supervisors do not easily accept changes in the curriculum.

French-Speaking Community Discussion

Session organisers: Hassane Darhmaoui (NAEC Maroc), Jacob Tolno Israel (NAEC Guinée), Frederic Pitout (NAEC France), Gilles Remy (OAE Node France), Emmanuel Rollinde (OAE Node France), and Abdelhafidh Teyehi (NAEC Tunisie)

Discussion summary

The francophone session was the occasion to gather together francophone NAEC. It was chaired by Emmanuel Rollinde and Estelle Blanquet. We shared each other's actions and needs, and discussed the 2023 edition of the workshop "Astronomie pour l'Education dans l'espace Francophone".

Five countries were represented by their NAEC. F. Pitout (France), Abdoulkarim Aliou (Mali), Julie Bolduc-Duval (Quebec/Canada), Gloria Raharimbolamena (Madagascar) and Nadeem Oozeer (Île Maurice). The situations are diverse, depending on whether astronomy is already in the curricula and on the link with the community of astronomers (observatory or research institutions) and with museums. Julie Bolduc mentioned the work of Pierre Chastenay about reasons given by teachers who are not teaching astronomy (https://clutejournals.com/index.php/JAESE/article/view/10221/10291).

We all agreed on the importance of the localisation of educational resources. Translations of English resources need to account for the educational specificities of each country. Beyond this, educational resources need to account for geographical and cultural specificities. The case of the southern hemisphere is emblematic since stars and constellations are not the same. Francophone countries are being spread around the world, and cooperation in sharing observations would be of great value.

The role of the newly created OAE Francophone Node at CYU (oaenf.cyu.fr) was presented. Every francophone actor is invited to register to the "annuaire des acteurs". The OAENF-CY node will specifically organize the second edition of the francophone workshop (astroedu-fr) that will be held in November 2023 in Tunis. The scientific committee involves (as of November 2022) the NAEC of Tunisia, Marocco, France, and Guinea, members of OAENF-CY, and members of astronomy education associations. We discussed the organization and possibility of funding so that we have at least one or two representatives of each francophone country where an NAEC has been designed. We came to the idea of different workshops where small groups do the activity and then create a resource that accounts for curricula, astronomy and STEM knowledge, learning and teaching difficulties, and implementation details. Those will be proposed as AstroEdu resources! More to come in January 2023 after the next meeting of the scientific committee of the workshop.

Portuguese-Speaking Community Discussion

Session organisers: Eduardo Penteado (OAE Heidelberg), Rosa Doran (NUCLIO, NAEC Portugal) and Thomson Mucavela (NAEC Mozambique)

Discussion summary

The Portuguese language is one of the most spoken in the world, estimated to be the native or second language of more than 270 million people worldwide, as well as the official language of several nations. Given its scope, it is natural that there is a relevant potential of collaboration regarding educational experiences among these countries. By gathering representatives of astronomy education from Portuguese-speaking countries in a round-table format event, this session aimed to promote discussions, foster exchange of experience and stimulate interaction and collaboration among all those interested in astronomy education.

As part of the discussion panel, there was: Eduardo Monfardini Penteado (coordinator at the IAU office of Astronomy for Education, as chair of the session, Brazil), Rosa Doran (co-chair, President of the executive council of Núcleo Interativo de Astronomia e Inovação em Educação and National Astronomy Education Coordinator for Portugal), Josina Nascimento (Brazil), Lara Rodrigues (Brazil and Chile), Sara Anjos (Portugal), Alvaro Folhas (Portugal) and Marcos Rincon (Brazil). Although the focus was astronomy education in Portuguese speaking countries, and therefore enrolled exclusively in the Portuguese language, representatives only from Brazil and Portugal were present. Nevertheless, this session also accounted for the presence of participants from other countries, totalling 15 participants.

Each of the participants presented their view about astronomy education in their countries, presenting also some parallels with other countries, such as in Chile, and their projects currently being developed. It is a consensus that astronomy carries a huge potential to foster high quality education although it still needs to be further developed in order to reach its full potential. The main bottleneck relies on the teacher formation. Since astronomy is not always present in their formation process, teachers often have some difficulties bringing astronomy to their students. Therefore, and although the presence of astronomy in the school curriculum is gradually increasing, making astronomy reach out to the students is still a structural problem, which requires efforts from different natures to be solved. For instance, projects such as teacher training could be more common and should take diversity according to regions (such as rural areas, undeveloped neighbourhoods, etc) and specific needs (such as accessibility, access to internet, etc) into account.

Citizen science projects also play an important role as these projects help both teachers and students to feel like science is something reachable and enjoyable, fostering a feeling of belonging, mitigating common stereotype views of science being made by eccentric people isolated in their labs. However, other issues not directly connected to astronomy education also play a role in the quality of science being taught in schools. We could cite the bureaucracies in which the school system is involved, and therefore difficulties to update curriculum; a huge workload and the responsibilities of teachers, the need to follow a strict curriculum; teacher devaluation such as low salaries; lack of investments on infrastructure, just to cite a few. This said, we can also recognise efforts being made and progress being reached. It is necessary, however, to reach out to government agencies to present possible solutions and to promote and strengthen international and institutional collaborations.

As a take home message, those present came up with the idea of creating a channel of communication to be used by teachers, astronomy education researchers, project coordinators and anyone else from the Portuguese speaking countries to keep sharing their experiences, ideas and difficulties in an attempt to help each other to solve problems and advance astronomy education in their countries.

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