OAE Mini-Review

Teaching with Astronomy Exhibits

Publications of the
IAU Office of Astronomy for Education

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

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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.

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Teaching with Astronomy Exhibits

Session organisers: Giuliana Giobbi, INAF-OAR - National Institute for Astrophysics, OAE Center Italy, Italy and Renate Hubele, Haus der Astronomie/ZAH, Heidelberg University, Germany

Session overview

This session focuses upon the use of easy-to-reproduce exhibits in contemporary interactive teaching of Astronomy in schools and for public outreach purposes. We invited a few astronomers and educators from various scientific institutes around the world, to find out about tools, ideas and techniques, and two speakers engaged in inclusive teaching, with exhibits dedicated to people with visual impairments. Wolgang Vieser, from the ESO Supernova Exhibition Centre, Germany, focused on a couple of workshops he and his colleagues have created, for introducing a few concepts of optics and astronomy to secondary school pupils. Rick Tonello, from the Gravity Discovery Centre located in Gingin, Western Australia, described their Space-time Simulator, an impressive exhibit that illustrates how gravity and mass induced space-time curvature work. Farprakay Jiarakoopt, from the National Astronomical Research Institute of Thailand, described two exhibits in detail, which can easily be reproduced and are useful to be applied in classroom activities for more effective lessons about basic concepts of astrophysics. B.S. Shylaja, from the Jawaharlal Nehru Planetarium of Bangalore, India, explained the use of a clock and another exhibit for a simple explanation of time, phases of the moon, and the orbits. Nicolas Bonne, from the Tactile Universe Outreach Centre at the University of Portsmouth, UK, illustrated the tactile models of galaxies they produced and used mainly with groups of blind and visually-impaired pupils and people. Amelia Ortiz Gil, from the University of Valencia, Spain, showed us the 3D tactile model of Mars prepared on the occasion of the "Inspiring Stars" Exhibition organized for the 100 years of IAU. We also had two poster contributions from Tan Jyh Harng (Singapore Science Centre) and Sitaram Bettadpur (Kolkata, India).

Engaging through DIY Workshops to Discover Scientific Principles and High-Tech Applications

Speaker: Wolfgang Vieser, European Southern Observatory, Germany

Effective learning relies on the involvement of as many senses as possible and a positive learning environment. ESO Supernova Planetarium & Visitor Centre, of the European Southern Observatory (ESO), is in high demand as an out-of-school learning location offering a varied education programme. In this talk, I wll explain how we engage students with the discovery of curriculum-related physical principles through hands-on workshops that make use of low-cost materials and easy to make, portable setups. With the example of our Telescope workshop, I will illustrate how both basic scientific principles and applications of modern engineering, e.g., for the Extremely Large Telescope of ESO, can be investigated by the students.

Talk link: `https://youtu.be/F2Ifo7OmbFY`

The European Southern Observatory (ESO) is the foremost intergovernmental astronomy organisation in Europe and well known for designing, constructing and operating powerful ground-based observing facilities. At its Headquarters in Garching near Munich, ESO is also running the ESO Supernova Planetarium & Visitor Centre that engages with more than 60000 visitors a year. The ESO Supernova (ES) is not only a free astronomy centre for the public with a state-of-the-art planetarium, a huge exhibition floor and seminar rooms for conferences, talks and workshops but also an out-of-school learning location that attracts approximately 9000 pupils (K-12) a year coming from 11 different countries (numbers from 2019). The permanent exhibition "The Living Universe" features 13 themes covering the science and technology behind modern astronomy, encompasses 2200 square meters of barrier-free exhibition space and is bilingual (English & German) throughout. The content is presented to the visitors in many different ways: interactive digital and physical exhibits, video and audio clips, large-scale images and models as well as panels and touch screens so that visitors can individually choose the depth of information.

Many studies indicate that there are positive long-term impacts of museum experiences and that learning actually happens in science centres (e.g. Falk et al., 2014). In contrast to everyday school life, "Scientific field trips to science centres can generate a sense of wonder, interest, enthusiasm, motivation, and eagerness to learn, which are much neglected in traditional formal school science" (Eshach 2007, p. 125). A field trip for pupils K-12 to ES includes a visit to a planetarium show, an age-appropriate guided tour of the exhibition led by an education specialist, a trained student or staff member from ESO's science or engineering department and an inquiry-based workshop led by an educator. This programme is free of charge and allows authentic experiences

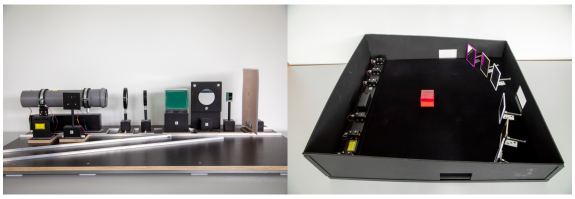

Figure 1: The setup of the "Catching Starlight" workshop (left) and the activity to introduce modern telescope technology to the pupils (right)

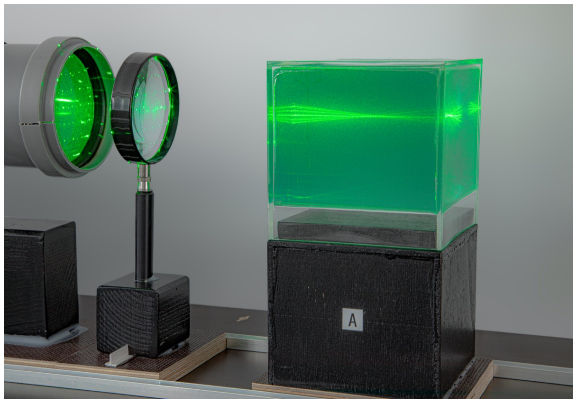

Figure 2: Focusing of parallel laser rays via a magnifying glass is made visible in the cube of coloured synthetic resin.

with science and technology in the context of autonomous, active, pupil-centred learning. It has been shown that this way of learning elicits extended engagement and self-directed inquiry (Allen, 2004) and supports intrinsic motivation, interest in science, self-confidence and science learning achievement (DeWitt & Storksdieck, 2008). Observations of school groups during a guided tour at ES show that especially the interactions with the guide, the possibility to ask questions and to have discussions among themselves, leads the pupils to be more cognitive and emotionally engaged during the visit than they were in the classroom. Since studies (e.g. Henriksen & Jorde, 2001) indicate that students' interaction with exhibits can generate and facilitate misconceptions, ES's interactive exhibits are part of the guided tour, so that the pupils already have a conceptual understanding of the exhibits before they go exploring on their own later on.

For the inquiry-based workshops, the essential design factors for exhibits, that allow a playful and exploratory discovery of scientific principles, and the curriculum relevant requirements are taken into account. The workshop design allows multiple opportunities for exploration and collaboration and also features phenomena that contrasted with pupils' previous experiences. The workshops also include cognitively challenging parts, allowing for internal differentiation and adaptation to different learning speeds. They are implemented in such a way that they can be easily replicated, repeated and enhanced in educational institutions or at home for low cost. The construction manuals as well as the student and teacher worksheets can be downloaded from ES's website.

The workshop "Catching Starlight" for example covers large parts of the curriculum topic "Optics". The objective is to find out more about lenses, how to classify and to combine them to build an optical device - in this case different telescope designs. When experimenting, additional phenomena can also be investigated, such as why the orientation of an image changes when seen through a lens, how to mix light of different colours, why an obstacle in the beam path like a secondary mirror does not lead to an incomplete image. The workshop consists of many activities that enhance scientific understanding via the method: predict, observe, explain. Like all our workshops, this one is also made of everyday materials (see Figure 1). A laser cannon, made out of a drainpipe, a laser pointer, a diffraction grating and a magnifying glass, generates many parallel laser beams with which the discovered principles can be validated and the focusing of light can be perceived as a three-dimensional process when the laser rays become visible inside the light ray block made of coloured synthetic resin (see Figure 2).

Although the used gadgets and implemented methods are engaging, the sole use of "old-style" telescope designs to find out more about optics is not particularly exciting for pupils. We therefore designed additional activities to make pupils familiar with modern telescope technologies, namely segmented mirrors and active optics that are used in ESO's Extremely Large Telescope. Here, the pupils need to focus parallel laser beams with the aid of six single flat mirrors (see Figure 1). The mirrors stick magnetically to the surface, can be moved and adjusted in their angle of inclination (with the help of "actuators"). Different ways of focusing the light are possible: prime focus, Cassegrain focus or Nasmyth focus.

The "Catching Starlight" workshop takes about 60 to 90 minutes in total and is very popular for pupils aged 10 – 15 years but is also extensively used for teacher training.

In total the ESO education programme offers six different workshops for different age groups (K-12). More workshops are in preparation as well as a professional evaluation of the workshops.

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Space-time Simulator Demonstration

Speaker: Richard (Rick) Tonello, Gravity Discovery Centre, Australia

In 1915, Albert Einstein published his celebrated "The General Theory of Relativity", the concept of curved space and warped time caused by the mass of an object was only within the grasp of professional physicists and well out of reach for the everyday layperson or school student. Using simple construction materials and methods, the "SpaceTime Simulator" (STS) has changed that by giving the teacher and student, the ability to observe a "simplified" version of Einstein's four-dimensional Spacetime. Using different mass spheres, the STS can now demonstrate and observe how objects are affected by the curved geometry caused by the mass of objects. A number of demonstrations can be performed utilising Space Time Simulator (STS). From demonstrating how a photon of light travels in a straight line with no mass present to how matter is "spaghettified" by the gravitational interactions of a simulated Black Hole.

Talk link: https://youtu.be/1bRyg8O4BN8

"Matter tells Space(Time) how to Curve; Space tells Matter how to Move".
-John Wheeler-

In 1915, Albert Einstein published his celebrated "The General Theory of Relativity", the concept of curved space and warped time caused by the mass of an object was only within the grasp of professional physicists and was well out of reach for the everyday layperson or school student.

This apparatus has changed that by giving the teacher and student the ability to observe a "simplified" version of Einstein's four-dimensional Spacetime. By the use of different mass spheres, they can now experiment and observe how objects are affected by the curved geometry caused by the mass of objects.

Equipment: The SpaceTime Simulator (STS) is very simple in its construction. The Gravity Discovery Centre's STS is made from an old trampoline frame that was recovered from a local recycling centre. The frame may be constructed from any number of materials (steel tube, aluminium or timber) depending on its availability and the skill of the person constructing the STS.

The circular design has proven to work the best, given when a mass is applied to the fabric, it produces an even curvature rather than a strange curvature produced by a square/rectangular frame. However, a square/rectangular can still work well enough to demonstrate curved Space-Time. The Fabric used is Lycra® or Spandex® . This material is durable, has the ability to stretch a great amount and return to its original form. One addition to the fabric would be grid-lines that may represent the dimension of Time. Time can be observed to remain constant (i.e. no stretching or compressing) when there is no mass applied and "stretch" when a mass is applied to the fabric.

The test masses (planets & stars) can be anything from golf balls, tennis balls, billiard balls, bocce balls, shot-puts/solid iron balls and even ten-pin bowling balls. A range of masses is ideal, a heavy mass to represent a star, an intermediate to represent a Super Jupiter/Jupiter planet, and numerous, lighter masses for small planets.

Demonstrations: As the video shows, a number of demonstrations can be performed utilising STS. From demonstrating how a photon of light travels in a straight line with no mass present to how matter is "spaghettified" by the gravitational interactions of a simulated Black Hole. The STS has been in use at the Gravity Discovery Centre for well over 15 years and has demonstrated to countless people how Gravity is an acceleration along the curved geometry of Spacetime.

We imagine that Albert Einstein would have been delighted to see his complex theory demonstrated in a manner that is understood by people of all education levels and ages.

Designing an Astronomy Exhibition to Support Outdoor Education for School

Speaker: Farprakay Jiarakoopt, National Astronomical Research Institute of Thailand

The astronomy exhibitions in Thailand were designed with the contents related to the basic education core curriculum in mind. The exhibitions feature interaction both via the use of technology and more traditional means to provide a better experience for the audience. The audience are encouraged to experience and promote inquiry to further explore the exhibits. The exhibition is produced in-house, therefore, visitors can easily deliver ideas of the exhibited equipment to apply with their activities in classroom. Our exhibition values lifelong learning and teaching, curiosity and inquiry, iteration and evidence, integrity and authenticity for sustainability. Examples of exhibition zones such as moon phases, scattering of light, and proof of the Earth's rotation by using the pendulum, etc.

Talk link: `https://youtu.be/RM65P1iA0SU`

The National Astronomical Research Institute of Thailand or NARIT is a research institute under the Ministry of Higher Education, Science, Research and Innovation. Its main missions are to carry out, support, and promote the development of astronomy and astrophysics in Thailand through research, public outreach, and educational activities. To raise awareness of astronomy, NARIT provides exhibition services for students and the general public across all regions in Thailand to explain the basic knowledge of astronomy by designing with the contents related to the basic education core curriculum in mind: Astronomy and Space. The exhibitions feature interaction both via the use of technology and more traditional means to provide a better experience for the audience. The audience are encouraged to experience and promote inquiry to further explore the exhibits. The exhibition is produced in-house including technologies, contents, infographics, etc. Therefore, visitors can easily deliver ideas of the exhibited equipment to apply with their activities in the classroom. Our exhibition values lifelong learning and teaching, curiosity and inquiry, iteration and evidence, integrity and authenticity for sustainability.

Objectives

1. To be a learning center in astronomy for local communities, schools, and universities to support astronomical academic services in school's curricula. And become the modern astro-tourism attractions of the region.

2. To be a learning resource where visitors can easily deliver ideas of the exhibited equipment to apply with their activities in the classroom.

3. To pursue knowledge and technology transfer in the field of astronomy.

Exhibition in AstroPark: The exhibitions feature interaction both via the use of technology and more traditional, emphasis on self-learning through devices and demonstration video. Furthermore, there are staff standbys to give more information to the visitor. There are two main exhibitions in AstroPark.

1. The Basic Astronomy Exhibition is inspired by basics of astronomy that can be seen in everyday life. Divided to 17 zones including Exploring the Solar system, Songs of the Universe, Moon Phases, Tides, Cosmic ray detector, Spectrum, Pattern in the sky, Aperture and Intensity, Seasons, Compare the weight on each planet, Your weight on other planets, Rotation of gas giant, Meteorite, Stellar evolution, The cosmic calendar, Foucault Pendulum, and Mission on Mars. In addition, the content and format of the exhibition are modified and updated to create a variety of learning.

2. The Astronomy Insight exhibition applied knowledge of fundamental physics and introduced in-depth astronomy data in the research field. There are 14 zones consist of Colors of light, Scattering of light, Refraction of light, The speed of sound, Pinhole Camera, Sundial, Liquid mirror telescope, Multiwavelength Astronomy, Infrared, Exoplanet exploration, Black Hole, Gravitational Lensing, Infinite reflections, and Astronomical phenomena.

Year-to-Date Operating Results: During July 2020 to July 2021 there were 160,945 people who visited the exhibition in AstroPark (temporarily closed due to COVID-19 in April to June 2021). And 1,160,290 people participated in the online events.


SEASONS


ASTRONOMY
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Future development and service plans: NARIT has plans to develop online learning materials on astronomy, virtual exhibitions with interactive activities in these virtual tours. To keep up with the changing era that focuses on online platforms which makes it easier and faster to access as well as transfer an astronomy exhibition into simple astronomy learning tools. By using the exhibition as a prototype, then applying the working principle to modify and create more simple equipment that can be easily found for further interactive learning activities in the classroom.

Astronomy Exhibits from Classroom to Demonstration Models

Speaker: Shylaja B. S., Jawaharlal Nehru Planetarium, Bengaluru, India

Teaching astronomy requires a platform which is different from the conventional blackboard technique. In this talk I would like to show some of the tools I utilised to explain the concepts like Lagrangian points (for Trojan asteroids) the duration of the day on different planets (especially Mercury), the difference between the phases of a moon through the month and during lunar eclipse and many more. A demonstrative exhibition called "Science in Action" which generally covers physics and chemistry was conducted with 20 such exhibits and attracted over 2000 visitors. All these exhibits will be discussed.

Talk link: https://youtu.be/1ZF35GEB_V0

Astronomy is quite a difficult subject to grasp for people of all ages - the reasons are many. Although quite sharp in grasping the mathematical essence, many falter while applying it to the sky. This implies that a physical model is essential to get the complete understanding of the subject.

In the last two and a half decades of my teaching astronomy for various age groups I have found that the exhibits, after all, have emerged out of classroom teaching experiences. We, as teachers, created some tools within our reach, including different approaches like role-play to communicate the essence effectively. Such humble tools transformed themselves to exhibits in the science parks and exhibition halls in the planetariums and the like. We hold 3-day exhibitions called "Science in Action", where the table top prototypes were demonstrated by students in the age group 12 to 15. As many as 30 such demonstration models made a huge collection. However the metamorphosis into larger gadgets (tamper proof and weatherproof) demanded a different approach - money being the main constraint.

The globe with its axis parallel to that earth has been very useful for demonstrations on Zero Shadow Day.

The models exhibited in the 3-day exhibition include the Vertical model.

The "Vertical" model

Almost all the exhibits, irrespective of the country of origin, invariably have a horizontal plane as the reference. Models to demonstrate the phases of the Moon or eclipses or even planetary motion assume the orbital plane of the earth to be parallel to the table / horizon. We may have inherited this from traditional globe makers who had to accommodate the 23.5 degree tilt of the rotation axis of the earth. Thus the concept of seasons, or even day and night, is easily understood inside the classroom but not so efficiently in the real sky. While explaining this I had to tilt the globe to make my standing posture parallel to a doll (a piece of chalk) representing me on the globe. (This idea transformed into a huge globe positioned parallel to earth's axis in the science park) Such an exercise repeated over several years resulted in the design of a model which I am explaining now. The model is named "vertical" model for quick identification. This has the plane of the ecliptic *perpendicular* to the plane of the table. The earth goes round the sun in the vertical plane. This immediately drives home the point that we turn "upside down" after 12 hours. I have found this gadget extremely helpful and it has always been reserved for the first session of the first day in any workshop. It makes a good beginning to explain the gradual change in the visibility of constellations throughout the year and throughout the night.

The meaning of full moon, new moon can be easily explained here although there is no provision to mount an object as the moon. Here, in India, the names of the months are coined in a special way and thus are known to laypersons. The full moon in March / April is seen near Spica. Its local name is *Chitra* and the name of the lunar month is *Chaitra*. Each month the star in the direction of the full Moon is different. The fan in the ceiling or a point on the table beneath or a light source elsewhere in the room - can all serve as reference stars to clarify this point.

The Clock as a teaching tool

The other easily available gadget is the mechanical clock which was a household item till the advent of its digital descendants. Still its usage is known to everyone and therefore, it becomes a very handy gadget for explaining various facts as we shall see now.

The discussion begins with the question on the interval between successive overlap of the hands of the clock. At 12:00 hours they overlap; at 6:03 hours the angle between them is 180 degrees. The students are asked - what is the interval after which this configuration repeats. The variety of answers (12 hours, 24 hours etc) leads to a good discussion and finally terminates at the correct answer - about 65 minutes. There are three periodicities here - hour hand of 12 hours, minute hand of 1 hour and the third is the 65 minute interval. A discussion on this quickly reveals that the three are interrelated. Knowledge of any two will fetch the third.

Senior students may be asked to derive the formula - it is pretty simple, and often finds a place in quiz question banks.

$$\frac{1}{t} = \frac{1}{T} - \frac{1}{T'}$$

T and T' are the periodicities of the hands and t is the interval between successive overlaps / constant angle difference.

1. **Sidereal time**
   It is very well known that the meridian transit of a star occurs 4 minutes earlier day by day. One hand represents the sun with a (diurnal) periodicity of 24 hours. The star arrives in advance by 4 minutes every day and will get aligned with the sun after 365.25 days. Putting these numbers into the formula we get the periodicity of the other hand - the duration of the sidereal day as 23 hour 56 minutes. However, we need to give values accurate to 4 or 5 decimal places to get this result. If we use sidereal day = 23.9344696 h, we get the duration of year as 365.2422326

2. **Orbital period of the Moon**
   The month has several definitions - the most popular one may be described as the interval from full moon to full moon (or new moon to new moon). We define the full moon to be represented on the clock by the two hands exactly separated by 180 degrees. One hand is the sun covering 360 degrees in 365.2422 days; the other hand represents the moon. The overlap occurs in 29.530588 days. Plugging these numbers into the formula we get the orbital period of the moon as 27.321661 days. This is the orbital period of the moon with reference to a star. Thus if we see the Moon very close to Aldebaran it will again approach the star after 27.32 days. This demonstration is very useful in explaining the lunar occultations and conjunctions. Here in India, the day is reckoned with the name of the star in conjunction with the moon. Thus the 27 stars attributable to the position of the moon are known to lay persons. They will be able to appreciate the meaning of sidereal month.

3. **Orbital period of planets**
   The hands of the clock now can be extended to understand the motion of planets. If one hand is Mars and the other sun, the 180 degrees position represents the opposition. The interval between successive oppositions can be deduced from patient observations as 780 days. When this is plugged into the formula, we get T' as the orbital period of Mars. Opposition measurements are not relevant for inner planets. Here the successive interval between maximum elongations can be used instead. The students were delighted to know that this method has been in use for more than 2000 years.

4. **Day and night on Mercury**
   Mercury with the orbital and revolution periods as 59 and 88 (earth) days, poses a challenge to imagine the duration of the day and night there. The clock depiction comes in handy there. Imagine yourself on Mercury going round once in 59 days. This represents

This clock depicts the position of the sun and the moon as well as the lunar phase.

one hand of the clock. The sun appears to go round Mercury in 88 days - this is the other hand of the clock. Plugging in the numbers to the formula, you will be wonderstruck. The sun will be at your zenith after 176 days - one "day" is equal to one and half "years"!! This can be used for Venus as well.

The Sun-Moon Clock

Even as we found this clock to be a very useful tool in the classroom, we implemented a large clock in the premises. The "Sun-Moon clock" has 3 m dial and the concealed hands to depict the positions of the sun and the moon in the sky as seen by the observer on Earth (the center of the clock). It shows not only their positions in the sky but the phase of the moon also. This is one example for demonstrating how a classroom discussion with a humble clock made its way to a large science park exhibit.

3D Planetary Tactile Globes for the "Inspiring Stars" Exhibition

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

Collaborators: J. Burguet-Castell, F. Ballesteros, M.J. Moya, M. Lanzara & M. Pallardó (University of Valencia Astronomical Observatory, Spain), and A. Fernández-Sot (IFCA (UNICAN-CSIC)) [1]

One of the exhibitions created for the 100th anniversary of the IAU in 2019 was "Inspiring Stars", an exhibit with the goal of showcasing examples of inclusion in astronomy. Our contribution to this project was a set of tactile 3D globes of the terrestrial planets and the Moon. They were specially designed to allow persons with visual impairments (BVI) explore by themselves the most relevant features of these celestial bodies. Initially the design and creation of the globes involved complex, but we eventually developed a software capable to produce efficiently 3D digital tactile models from 2D maps. All the models, the software to make them and a couple of activity books are available for downloading at the projectŐs website: "A Touch of the Universe" (https://www.uv.es/astrokit/).

Talk link: https://youtu.be/8icU6LnJ8XA

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In 2019 the International Astronomical Union celebrated its 100th anniversary with activities and exhibitions all around the world. One of those exhibits was "Inspiring Stars", which focused on a range of examples of inclusion in astronomy, from underrepresented groups to people with disabilities.

Our contribution to "Inspiring Stars" was the creation of a set of tactile 3D globes of the terrestrial planets and the Moon (Figure 1). They were specially designed to allow the blind and visually impaired (BVI) to explore by themselves the most relevant features of these celestial bodies. The final models were put to test by BVI astronomers and also users from the general public. The feedback that we gathered allowed us to improve the tactile planetary globes.

[1] This work has been funded by the project PID2019-109592GB-100/AEI/10.13039/501100011033 from the Spanish Ministerio de Ciencia e Innovación - Agencia Estatal de Investigación.

From maps to 3D tactile globes, with Mapelia

Initially, the design and creation of the globes involved several steps of diverse complexity, starting with the edition of the original 2D map to increase the image contrast and smooth out the excess details, in order to obtain a tactile representation of the most important features while getting rid of too much details that make the model confusing when touched for the first time by a blind person. After image editing, as we are astronomers, we used IRAF to create an ascii file from the image in polar coordinates, adding the pixel brightness in each position. Then a 3D rendering software was used to translate the data into a 3D file of the tactile globe [1]. The whole process was long and tedious and prone to introducing errors in the final 3D files. Therefore, we set out to develop a software, called *Mapelia*, that can do the job easily, helping us and also the rest of educators and researchers who could then create their own models [2].

Mapelia is a tool written in Python that uses as input jpg or png files that contain maps (that is, gridded datasets where the value of each pixel is the elevation, brightness or whichever property we wish to render in each case) in any of the following projections: equirectangular, Mercator, central cylindrical, Mollweide or sinusoidal. The output of the program is a 3D file (of polygons like .ply or .stl, or points in space like .asc), that can be visualized and manipulated with programs like MeshLab or Blender. *Mapelia* is accompanied by its "friends" *guapelia*, *pintelia*, *poligoniza*, *stl-split* and *smooth*, which add some other functionalities. In particular, *guapelia* is a GUI to use *Mapelia*, and *pintelia* converts maps into coloured 3D images. All the models, the software to make them and a couple of activity books are available for downloading at the website of the project "A Touch of the Universe" [3].

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3. A Touch of the Universe, https://astrokit.uv.es

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

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

Astronomy is a topic that engages and inspires a wide range of audiences around the world, but blind and vision impaired people can often find it difficult to engage with the subject due to its very visual nature. The Tactile Universe is an award winning public engagement project based at the University of Portsmouth which is opening up current topics in astrophysics research to blind and vision impaired people through accessible tactile resources based on real data. We will discuss how involving the vision impaired community in the development of these resources has made them truly unique and versatile.

Talk link: https://youtu.be/btRPHqTTYz0

Astronomy is a topic that engages and inspires a wide range of audiences around the world, but blind and vision impaired (BVI) people can often find it difficult to engage with the subject due to its very visual nature. The Tactile Universe is an award-winning public engagement project based at the University of Portsmouth which is opening up current topics in astrophysics research to BVI people through accessible tactile resources based on real data. The project's aim is to demonstrate to this community that astrophysics can be accessible and, in particular, raise the aspirations of young BVI people. The project is led by vision impaired astronomer Nic Bonne.

The core resources of the Tactile Universe are tactile 'height map' images of galaxies, referred to as models. These are created digitally using a custom plug-in created by project technical lead Dr Coleman Krawczyk for the open-source 3D modelling software package Blender. Using monochrome galaxy images, the plug-in maps the image to a 3D surface, where the height of the surface scales directly with the brightness of the corresponding image pixel. The brighter the source image pixel, the higher it is from the base of the model, the darker the pixel, the closer to the base of the model. Physical models can then be produced through techniques like 3D printing and users can feel the shape and features of a galaxy through changes in brightness by running their hand across the model, without the need to see it. An example of an Sloan Digital Sky Survey (SDSS) observation of galaxy Messier 51 (the Whirlpool galaxy) and its corresponding tactile model are shown in Figure 1.

To prototype and develop this basic idea, the Tactile Universe was funded by the South East Physics Network to run a 6-month pilot project in 2016. One of the challenges in developing accessible resources for the BVI community is that every person with a vision impairment is unique, both in terms of the nature and degree of their sight loss, but also in how they have individually adapted to this. To ensure that our tactile images worked for as many different

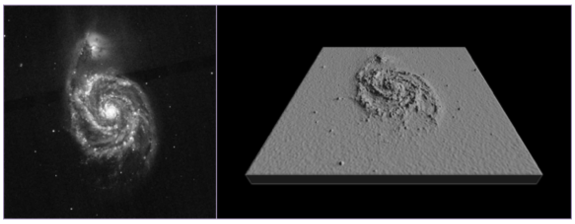

Figure 1: An SDSS image of galaxy Messier 51 (left) and the corresponding tactile model produced using the Tactile Universe's custom Blender plug-in (right). The height of any point on the surface of the model scales with the brightness of the image's pixels.

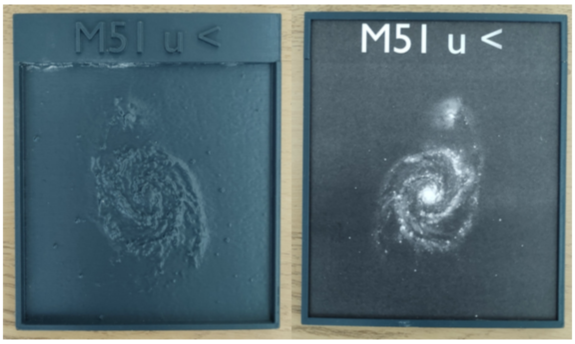

Figure 2: 3D printed tactile models of galaxy Messier 51 from the front and the back. On the front (left) the models include the tactile surface, a tactile name plate for easy identification, as well as a raised border around the edge of the model which is the height of the brightest point in that image. The back of the model (right) has a mirrored print-out of the image used to make the model, so that users with some vision can look at this while touching the corresponding tactile features on the front.

people as possible, it was crucial to involve the BVI community in further developing our resources. To facilitate this, we tested our tactile model concept with a BVI support group based in Portsmouth, so that we could get their feedback.

Initially, we produced a series of tactile images of galaxies with a variety of tactile heights (the distance between the dimmest and brightest point on the model) ranging from 1mm to 5mm. The consensus from the group was that a tactile height of 3mm was the best option, as more gradual changes in brightness could still be perceived, and abrupt changes in brightness (as in the case of foreground stars) were not so sharp as to be unpleasant to touch. We also produced models of different sizes. Models roughly the size of a postcard were the preferred option, as these were easy to handle, and were not so large that participants got lost as they felt their way across them.

Members of the support group also provided suggestions that allowed us to improve the models in other ways. To allow users with some vision to use their tactile and visual senses, we added a print-out of the original galaxy image used to make the model to the model's back face, mirrored so that it would directly correspond to the tactile features on the front. Participants also wanted a way to judge how high or 'bright' any part of the model was. The solution was to add a raised reference border around the tactile image which has the same height as the brightest tactile feature. Users can easily compare this to whichever part of the model they are exploring. Lastly, to allow users to quickly identify which model they were handling, we developed tactile name plates which sit at the 'top' of each tactile image. These name plates are particularly useful when jumping between sets of these models where we use multiple versions of the same galaxy in different wavelengths. The 3D printed models with all of these features can be seen in Figure 2.

During these test sessions we quickly realised the importance of appropriate descriptions and explanations to support users in understanding these models. Working with this group, we were able to find analogies and comparisons that worked. For example, using rugby balls and CD's to describe the 3D shapes of elliptical and spiral galaxies, and demonstrate how we perceive galaxies from different angles; linking the idea of colour in a galaxy to the temperature of its stars; comparing the structure of a galaxy to a rain cloud etc.

Beyond this pilot, the Tactile Universe received funding from the Science and Technology Facilities Council to expand its reach and to further develop its resources for applications to a classroom setting. Working with BVI students from local primary and secondary schools we have developed a series of lesson plans that incorporate models of a variety of distinct galaxy types, alongside language, descriptions and analogies that are accessible to BVI participants, but can also benefit sighted classmates. These workshops begin with local scales and sizes in our solar system, build up to Milky Way scales, and finally discuss galaxies in their many different forms.

To allow anybody to access these resources (3D printable models, Blender plug-in, lesson plans and scripts for primary and secondary school students) we have shared them online for free. They can be downloaded from our project website (www.tactileuniverse.org).

Engaging with the BVI community throughout this project has been a sometimes challenging but ultimately rewarding experience. By working with the BVI community from the beginning and by listening to their feedback and suggestions, our resources are more versatile, and how we use them to engage the community has been improved in ways that would not have been possible without their input.

Teaching with Astronomy Exhibits

Presenter: B. R. Sitaram, Zeal Education, Ahmedabad, India

In this poster my collection of Astronomy teaching aids is presented. These include the sunrise locator, sunrise timer, sub-solar point model, seasons models, moon phase calculator, constellation charts, guess the constellation, etc. All these are actual hands-on models, not computer apps and can be easily assembled by students. As an example, the sunrise locator and timer shows you the location and time of sunrise/set at any latitude on any day of the year.

Poster link: https://astro4edu.org/siw/p77

These are some Astronomy teaching aids that I have designed (https://www.teacherspayteachers.com/Store/Sitaram-Bettadpur). All these are actual hands-on models. We regularly conduct workshops where students are sent kits in advance and they assemble and learn how to use them. These, and similar models in science and maths, have proved to be very popular with students. The models discussed are:

1. Sunrise Timer: Shows the time of sunrise on any date at any location: Useful in explaining seasons (duration of sunshine).

2. Sunrise Locator: Shows the location of sunrise on any date at any location. Useful in explaining seasons (angle at which sunshine strikes ground).

3. Sub-solar point model: Shows the subsolar point (point on earth's surface where the sun is at the zenith) at the instant of observation. Useful for showing apparent north-south movement of the Sun.

4. Moon phase calculator: Finds the phase of the moon on a specific date. Important for sky-watch planning, timings of tide and for festivals based on the lunar calendar.

5. Ephemeris: Shows celestial longitude of Sun, Moon and planets over a calendar year. Shows difference in speed of movement across sky, possibility of seeing a planet on a particular night, phase of the moon, retrograde and prograde motions.

6. Solar System Distances Strip: A long (5 m) strip that concertina folds into a pocket map showing the distances between the sun and planets. Also shows the Sun to scale, showing how vast the system is even compared to the Sun.

7. Constellation cards: A jig-saw puzzle with constellations represented in three forms: only stars, stars with connecting lines and with imaginary figures superimposed.

Starry Starry Night

Presenter: Tan Jyh Harng, Singapore Science Centre, Singapore, Malaysia

Constellations are excellent stepping stones for young children when they begin learning astronomy. It is common pedagogy involving storytelling when it comes to learning. Constellations have rich stories behind them which makes them easy to teach children. From there, it is easy to link up to other areas as well, such as the names of the major stars and also seasons as well. In this exhibit and activity, a star chart is made with sticks representing as stars and rubber bands as the imaginary connecting constellation lines. Children can practice remembering the constellations by 'connecting the lines' using the rubber bands.

Poster link: https://astro4edu.org/siw/p21

It is common pedagogy involving storytelling in early childhood education. Hence, constellations are suitable for young children due to the rich mythologies involved. Using these stories, other topics of Astronomy can be introduced as well. In this exhibit, a star chart is made with sticks representing stars and rubber bands as the imaginary connecting constellation lines. Children can practice remembering the constellations by 'connecting the lines' using the rubber bands. Located in Science Centre Singapore, KidsSTOP™ is a dedicated Children's Science Centre. One of the interactive exhibit booths that KidsSTOP™ has is the Starry Starry Night. This booth uses plastic tubes of various diameter to represent the stars of the night sky. Children can make use of the rubber bands to connect the plastic tube together to form the imaginary lines of the constellation.

With the common constellations already traced out, children can follow it to 'connect' the stars. This process can help them familiarise with the shape of the constellation. Alternatively, children may also use their own creativity to connect the plastic tubes to trace out their own constellation or asterisms. Educators may also use the opportunity to teach of the term asterisms, commonly identified patterns of stars that are not a constellation. To enhance the visual appeal of the exhibit, fluorescent materials are used in the plastic tubes. Under black light, the 'stars' can appear to glow.

A challenge of the Starry Starry Night exhibit is the height of the wall. As the star map is relatively tall, younger children may have issues reaching the 'higher' stars. Use of a stool or making the star map wall smaller are possible mitigation methods. Such interactive exhibit can also be made into smaller-scale hands-on activity. For example, using toothpicks on a foam/cork board to create a star map and thereafter using rubber bands or strings to trace out the constellations. For more information about Science Centre Singapore and KidsSTOP™ , visit https://www.science.edu.sg/.

One entry point of KidsSTOP™.

Starry Starry Night exhibit.

An example of a self-created asterism in the constellation of Orion.

Discussion summary

In the first discussion session, we received a certain number of questions addressed to Nicolas Bonne, concerning the 3D Models he introduced in his presentation, which he uses for Astronomy teaching and outreach purposes, mainly aimed at the visually-impaired, blind pupils, and the general public. In particular, he was questioned about the size of the models, the type of 3D printers used, the difficulties he experienced in people's feedback, and the lessons learned. Nicolas answered promptly, with indications about the size of the models, the link for downloading the globes' files, and the models of 3D printers used by his team. He also described the mixed reactions of children and the general public, which could help decide possible modifications of the models. We then asked Amelia Ortiz-Gil whether her team carried the 3D globes in the school's classrooms, and whether she was thinking of producing other globes and other exhibitions after the "Inspiring Stars" exhibit. Amelia confirmed that the globes had been used in Spanish schools, whereas the exhibition was travelling in other European countries, Italy in particular. As hosts, we then asked Wolfgang Wieser how he had adapted his workshops to a virtual format during the pandemic, the challenges he faced, and whether his team had produced a virtual tour of the large and interesting ESO Supernova exhibition halls. Wolfgang confirmed that online workshops had been prepared and widely used during the lockdown, and a lengthy virtual tour had been produced by his colleagues. Finally, we asked Farprakay Jiarakoopt whether they organized teacher training courses, and indeed we discovered that NARIT offers courses at various levels and focused on different topics of Astronomy and Astrophysics.

In the second discussion session, we started by asking Rick Tonello to describe his experiences travelling with a telescope for stargazing activities in various villages of Western Australia. Rick described his "adventures in the bush" and the enthusiasm of the public during stargazing nights. Since he was also asked about the fabric used for his space simulator and the issues faced with the public, he gave details about Spandex and funny anecdotes on people's questions and reactions. Nicolas was asked about the possibility of creative labs for visually-impaired pupils, and he said it would be a good idea and they would think about it. Wolfgang was asked about the role of interactivity in his workshops, and he confirmed this was indeed the core of such teaching activities. B.S. Shylaja was asked about the age-group of pupils that her classes are aimed at. She confirmed there were labs aiming at different age groups. Amelia was asked about the best possible feedback she had received from the public, and she described very moving and rewarding episodes. Finally, on request, we allowed Jan Sermeus, from KU Leuven University Planetarium, Belgium, to announce the survey organized by his team about planetarium activities and needs in various countries.

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