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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

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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).

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:

OAE Center Italy
OAE Center China, Nanjing
OAE Center India
OAE Center Cyprus
OAE Center Egypt
OAE Node France at CY Cergy Paris University
OAE Node Republic of Korea
OAE Node Nepal

Insights from Astronomy Education Research

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,

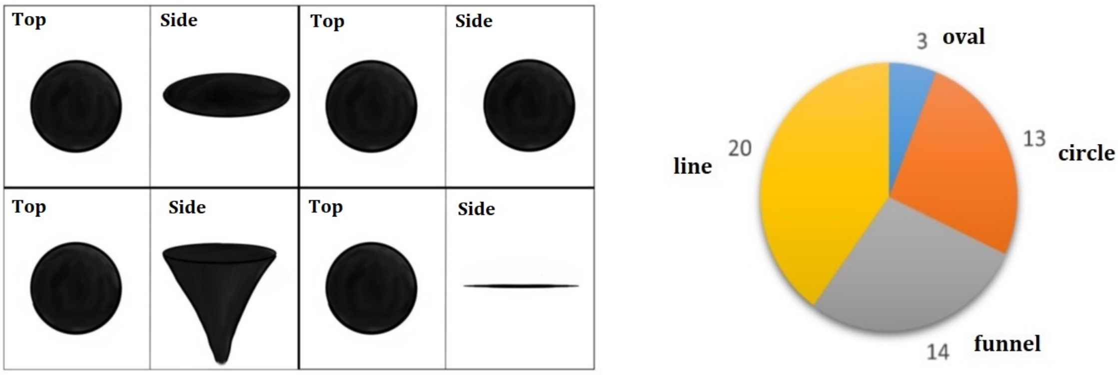

Figure 1: The four types of black hole shapes the participants drew.

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

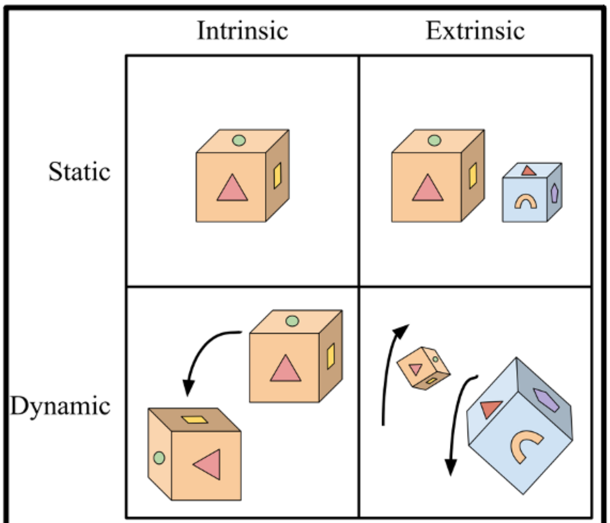

Figure 1: Classifications of cognitive process in the distributed spatial skill quadrants. Figure adapted from Uttal et al. (2013).

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/a5CAfPghOn0

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.

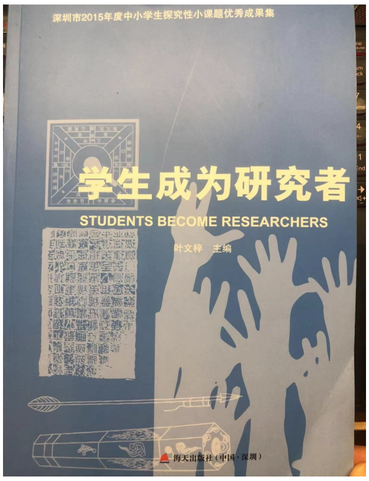
Talk link: https://youtu.be/nR5maBiXe-s

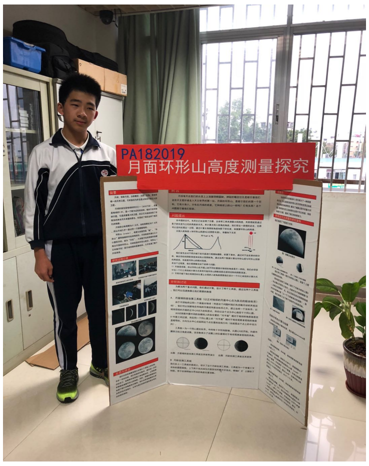
We provide a basic astronomy course, once a week every semester. We help interested students take part in Mini Exploratory Research. From 2015 to 2016, our first Mini Exploratory Research topic *How high are the Lunar craters?* was approved by the Shenzhen Institute of Education Sciences. With their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

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.

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