OAE Mini-Review

Astronomy Across Disciplines and Borders

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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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Astronomy across Disciplines

Session organiser: Stefano Sandrelli,
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Session overview

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

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

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

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

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

Talk contributions

Collaborations and Collisions in Science & Art

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

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

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

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

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

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

Art-Science Collaborations at MIT: Case Studies

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References:

- Fraknoi, A. Astronomical Society of the Pacific: EDUCATION & OUTREACH: Resource Guides: Science Fiction Stories with Good Astronomy & Physics: A Topical Index (2015). Available at: https://astrosociety.org/education-outreach/resource-guides/science-fiction-stories-with-good-astronomy-physics-a-topical-index.html (Accessed: 9th September 2021)

- Furman, O., Dorfman, N., Hasson, U., Davachi, L., & Dudai, Y. (2007). They saw a movie: long-term memory for an extended audiovisual narrative. Learning & memory, 14(6), 457-467.

- Glaser, M., Garsoffky, B., & Schwan, S. (2009). Narrative-based learning: Possible benefits and problems. Communications, 34(4), 429-447.

- Jordan, P., & Silva, P. A. Building an argument for the use of Science Fiction in HCI Education. In International Conference on Intelligent Human Systems Integration (pp. 846-851). Springer. (2019).

- Nováková, Julie (European Astrobiology Institute, 2020): STRANGEST OF ALL: AN ANTHOLOGY OF ASTROBIOLOGICAL SF. Available at: https://www.julienovakova.com/strangest-of-all/ (Accessed: 9th September 2021)

- Thévenon, M. Using Science Fiction as a Teaching Tool in ESP Classes for Science Students. ILCEA. Revue de l'Institut des langues et cultures d'Europe, Amérique, Afrique, Asie et Australie, (31) (2018).

- Vrasidas, C., Avraamidou, L., Theodoridou, K., Themistokleous, S., & Panaou, P. Science fiction in education: Case studies from classroom implementations. Educational Media International, 52(3), 201-215 (2015).

- Wolfe, M. B., & Mienko, J. A. (2007). Learning and memory of factual content from narrative and expository text. British Journal of Educational Psychology, 77(3), 541-564.

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

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

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

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

Talk link: https://youtu.be/kEM1GhuAPPg

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

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

A curricular case study in Chile:

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

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

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

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

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

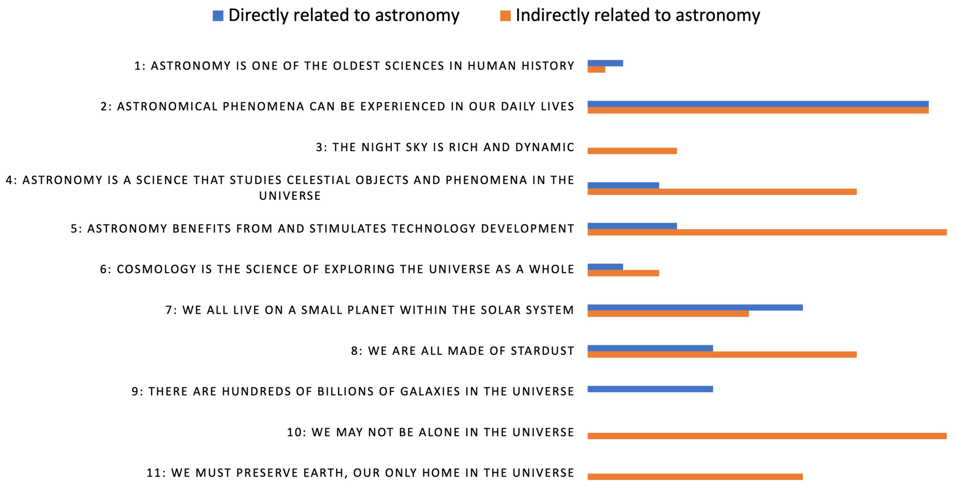

Figure 1: Micro-objectives (m-os) classification in terms of the Big Ideas in Astronomy (BIA).

Practical examples: interdisciplinary astronomy classroom units

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

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

Discussion and conclusions

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

References:

1. National Research Council (2001), Astronomy and astrophysics in the new millennium. Washington, The National Academies Press

2. Percy, J. R. (2006). Teaching astronomy: why and how? Journal of the American Association of Variable Star Observers, 35, 248-254. Retrieved from: http://adsabs.harvard.edu/pdf/2006JAVSO..35..248P

3. Salimpour, S., Bartlett, S., Fitzgerald, M.T., McKinnon, D. H., Cutts, K. R., James, C. R., Ortiz-Gil, A. et al. (2020). The gateway science: a review of astronomy in the OECD school curricula, including China and South Africa. Research in Science Education. doi: https://doi.org/10.1007/s11165-020-09922-0

4. Retrê, J., Russo, P., Lee, H., Salimpour, S., Fitzgerald, M., Ramchandani, J., Schrier, W. et al. (2019) Big Ideas in Astronomy: a proposed definition of astronomy literacy. International Astronomical Union Commission C1 Astronomy Education and Development.

5. Ruiz, M., Montenegro, M., Meneses, A., & Venegas, A. (2016). Oportunidades para aprender ciencias en el currículo chileno: contenidos y habilidades en educación primaria. Perfiles Educativos, 38(153), 16-33. doi: https://doi.org/10.22201/iisue.24486167e.2016.153.57633

6. Anderson, L., & Krathwohl, D. (2001), A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives, New York, NY: Longman.

Teaching Critical Thinking Skills with Astronomy

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

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

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

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

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

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

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

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

Media and information literacy

Identify the sources

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

Reading images and graphs

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

Cognitive biases

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

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

References:

- CLEA (Coll.), Croyances et idées fausses en astronomie, hors-série des Cahiers Clairaut n° 13, 2020. https://ventes.clea-astro.eu/hors-serie/154-hs13-croyances-et-idees-fausses-en-astronomie.html

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

Integrating Earth & Space Science Education in our Schools

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

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

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

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

CALL TO ACTION:

To effectively bundle and advance Earth & Space Science education worldwide, our stakeholder institutions need to do a better job of interacting, cooperating, and coordinating. They include

1. Earth & space science organizations (e.g. NASA, ESA, IAU, AGU, EGU, AAS, etc.)
2. Science and education departments in colleges and Universities.
3. National associations of science educators (NSTA, NAGT, NESTA, NASE, ASP, etc.)
4. State boards of education (MA DESE, CA Dept. of Education, etc.)

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

Teaching the History and Philosophy of Astronomy

Presenter: Chris Impey, University of Arizona, USA

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

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

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

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

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

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

Raising the Interest and Reaching out with Interdisciplinary Astronomy

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

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

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

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

Astronomy and sports – Equestrians sports

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

Astronomy and Art – The phases of the moon

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

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

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

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

Resources:

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

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

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

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

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

Teacher Workshop for the Design of Astronomy Interdisciplinary School Lessons

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

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

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

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

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

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

References:

- Begg, M. D., and R. D. Vaughan (2011). Are biostatistics students prepared to succeed in the era of interdisciplinary science? (and how will we know?). American Statistician 65(2):71-79.

- Cabezón, S., & Rodríguez, V. (Eds.) (2016). Alcanzando las estrellas: hallazgos de las cumbres chileno-estadounidenses de educación y difusió n de la astronomía. Retrieved 27 April 2020 from http://www.aui.edu/wp-content/uploads/2016/12/Reaching-for-the-Stars_lg.pdf

- Marinovic, F. (2016). Estudio Astronomía y Marca País: una mirada desde la opinión pública chilena. Santiago: Fundación Imagen de Chile.

- National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2005. Facilitating Interdisciplinary Research. Washington, DC: The National Academies Press. https://doi.org/10.17226/11153.

- National Research Council (2010). New Worlds, New Horizons in Astronomy and Astrophysics. Washington, DC: The National Academies Press. DOI: https://doi.org/10.17226/12951.

- National Research Council (2001). Astronomy and Astrophysics in the New Millennium. Washington, DC: The National Academies Press. DOI: https://doi.org/10.17226/9839.

- National Research Council (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press. DOI: https://doi.org/10.17226/13165

- Rodrigues, L., Montenegro, M., Meneses, A. (2021) Interdisciplinary links between the curriculum and the Big Ideas in Astronomy: a case study in Chile. Oral presentation at the

3rd Shaw-IAU Workshop on Astronomy for Education.

- Salimpour, S., Bartlett, S., Fitzgerald, M.T., McKinnon, D. H., Cutts, K. R., James, C. R., Miller, S., Danaia, L., Hollow, R. P., Cabezon, S., Faye, M., Tomita, A., Max, C., de Korte, M., Baudouin, C., Birkenbauma, D., Kallery, M., Anjos, S., Wu, Q., Chu, H., Slater, E., Ortiz-Gil, A. The Gateway Science: a Review of Astronomy in the OECD School Curricula, Including China and South Africa. Res Sci Educ (2020). DOI: https://doi-org.pucdechile.idm.oclc.org/10.1007/s11165-020-09922-0

Bringing the Sun to School

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

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

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

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

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

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

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

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

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

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

Virtual Reality for Astronomy Education

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

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

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

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

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

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

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

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

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

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

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

References:

- Nooriafshar, Mehryar & Williams, Ron & Maraseni, Tek. (2004). The use of virtual reality in education. 6-8.

- Shapiro, Lawrence & Stolz, Steven. (2019). Embodied cognition and its significance for education. Theory and Research in Education. 17. 19-39. 10.1177/1477878518822149.
- Puentedura, R. (2014b). Learning, technology, and the SAMR model: Goals, processes, and practice

Providing Education through Astronomy Clubs

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

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

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

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

Astronomy Education Without Borders

New approaches for international cooperation about Astronomy

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

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

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

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

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

Discussion summary

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

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

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

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

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

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