

Astronomy Education Conference

Bridging Research & Practice



Editors

Paulo S. Bretones
Urban Eriksson
Pedro Russo

ASTROEDU MEETING 2019

Astronomy Education Conference

Bridging Research & Practice

Editors

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(Universidade Federal de São Carlos, Brazil)

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Preface

The field of astronomy education has grown significantly over the last few decades, with an increasing number of research articles having been published by a growing number of academic and practitioner groups. Despite the diverse and large number of astronomy education events and conferences, there has been no regular international conference place for astronomy education researchers and practitioners worldwide to convene and discuss their work in the field. Hence this meeting was intended to be the first of a regular, biannual, IAU Commission C1 Astronomy Education Conference with an aim to increase the quality, quantity, community and impact of astronomy education research and practice. The idea was to have a regular Astronomy Education Conference in the same manner as the CAP Conference, biannually but in alternate years to CAP. Holding regular meetings would be beneficial to build the community in the field. Following the last CAP meeting held in 2018, we arranged the first AstroEDU conference in 2019. This was the first of a bi-annual Astronomy Education Conference that the IAU Commission C1 organised and celebrates the 100 Years of the IAU. The first biannual **AstroEDU Meeting: Astronomy Education Conference: Bridging Research & Practice** was held at ESO Supernova Planetarium, Garching, Munich, Germany from 16 to 18 September 2019.

This conference brought together astronomers, astronomy education researchers and education practitioners to communicate, discuss and tackle common issues. The three key topics spanned traditional and practical research exploring the purely theoretical to issues encountered attempting to embed research results into practical situations, usually mediated by standards, curriculum and instruction. The conference also provided an opportunity for the community to discuss the results in astronomy education stemming from the IAU Strategic Plan 2010-2020 and discuss the requirements for meeting the next IAU Strategic Plan goals regarding astronomy education.

The key topics were:

- Astronomy Education Research;
- Astronomy Education Standards, Curriculum and Instruction and
- Bridging research and practice in Astronomy Education.

There were 114 Participants from 25 Countries, 44 Talks, 10 Workshops and 50 Posters and the three keynote speakers discussed some cutting-edge topics in astronomy education:

- Astronomy Education Research (Janelle M. Bailey, Temple University, Philadelphia, USA)

- Astronomy Education Standards, Curriculum and Instruction (Robert Hollow, Astronomy and Space Science, CSIRO, Australia)
- Primary and Secondary Teacher Education (Agueda Gras-Velazquez, Scientix, European SchoolNet, Brussels, Belgium)

The IAU President, (Ewine van Dishoeck) and the IAU General Secretary (Teresa Lago) also attended and contribute to this conference.

Following the conference, this book is composed into three main sections:

- Session I – Complete Papers – Oral Presentations;
- Session II – Complete Papers – Posters;
- Session III – Abstracts.

Finally, we would like to express our deepest thanks especially to the colleagues from ESO Supernova, in particular Tania Johnston and Wolfgang Vieser, and also Michael Fitzgerald and Saeed Salimpour for all their efforts to make everything about registrations, abstract reviews, schedule, website, grants and communication with the participants run so smoothly as it did.

We hope to meet you soon in the next IAU C1 astroedu conference!

Paulo S. Bretones
Urban Eriksson
Pedro Russo

IAU C1 AstroEDU conference Chairs and Editors

Additional information

- Bretones, P. S. (2019). A history of IAU Commission C1: a look from the Newsletters. In: 349th Symposium of the International Astronomical Union, Under one sky: the IAU Centenary Symposium, 2019, Vienna. Under one sky: the IAU Centenary Symposium. Cambridge: Cambridge University Press, 2018. v. 1. p. 419-430.
- Bretones, Paulo S., & Neto, J. M. (2011). Astronomy Education Review. Astronomy Education Review, 11(1), 010108. <https://doi.org/10.3847/AER2012011>
- Vieser W. et al. – Report on the IAU Conference “Astronomy Education — Bridging Research & Practice”, The Messenger, No. 178 – Quarter 4, 2019, p. 63-66, at: https://www.eso.org/public/archives/messengers/pdfsm/messenger_0178.pdf



astroEDU Conference
2019 group picture
at Supernova, ESO.
Credit: L. Calçada/ESO



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IAU Astronomy Education
Conference. ESO Director
General Xavier Barcons
addresses the participants.
Credit: ESO





Session

*Complete Papers –
Oral Presentations*

I

Session I.I

*Astronomy
Education Research*

AER Pathways: Recent Research and Future Directions

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Abstract

Astronomy education research (AER) offers insights into a variety of topics, such as teaching and learning across formal and informal settings, professional development for teachers and faculty, attitudes and beliefs about astronomy, and public understanding of astronomy topics. The field has broadened dramatically from focusing on identification of naïve conceptions and the evaluation of teaching strategies. Collaborations across many settings and areas of expertise are allowing astronomy education researchers to push boundaries into new areas of research. Likewise, publication venues vary widely, providing both opportunities and challenges to researchers who want to share their research with the larger community. Future directions for AER include but are not limited to improved methodological designs, such as the use of mixed methods or robust quantitative analyses; longitudinal studies; and new topics such as spatial thinking in astronomy, motivation and related constructs, and the use of visualizations and simulations.

1. AER Pathways: Recent Research and Future Directions

Astronomy education research (AER) feels relatively new—maybe about 25 years old—but in fact it has roots that are older than one might expect. This paper will provide a general overview of some of the history of AER as well as to make some recommendations for future directions. This history is generally limited to research published in English, or with at least English translations or abstracts available, but there is more AER being conducted beyond this partial view.

2. An Overview of Past and Recent Research

2.1 Previous Reviews of the Literature

Wall (1973) provided the first published review of AER. This review included 58 studies relating to astronomy education. Wall categorized the studies by their partici-

pants' grade level: elementary studies, secondary studies, and college/adult studies, with comparable numbers of each. He created additional categories to describe the type of study: achievement studies, status studies, and curriculum studies. The research was presented based on the original grade-level classification first, then the type of study second.

Bailey and colleagues (Bailey, Prather, & Slater, 2004; Bailey & Slater, 2003, 2005) provided a series of related reviews that updated the work of Wall (1973). They did not focus on the grade level but instead concentrated on the research purpose, finding two primary groupings. The majority of the studies focused on students' (or teachers') understanding of astronomical topics, often including the identification of alternative (i.e., non-scientific) conceptions. Astronomical topics of interest were primarily related to Earth, such as the day/night cycle, seasons, lunar phases, and Earth's shape and gravity. A few later studies, typically focused at the college level, included topics such as astrobiology or cosmology. The second grouping of studies focused on the efficacy of particular instructional strategies for learning astronomical topics.

Lelliott and Rollnick (2010) conducted a review of literature specifically targeting K-12 students and teachers as well as informal education, omitting any studies that focused on college students. Their topical categories were similar to those of Bailey and Slater (2003). Five of the "big ideas" they identified (conceptions of Earth, gravity, the day/night cycle, seasons, and the Earth–Sun–Moon system) accounted for 80% of the 103 included studies.

In addition to these broader reviews of AER, a number of focused reviews have been published. Albanese, Danhoni Neves, and Vicentini (1997) reviewed the literature about "Earth and its place in the Universe" (p. 573), finding that although there was consistency in findings among studies around Earth's shape, the same was not true for research around the position of Earth relative to other objects. Agan and Sneider (2004) also looked at studies around Earth's shape and gravity and made recommendations for curriculum development to provide an appropriate foundation for future learning about astronomy. Kavanaugh and Sneider (2007a, 2007b) reviewed literature around students' understanding of gravity, with different articles for free fall and trajectories/orbits. Brazell and Espinoza (2009) conducted a meta-analysis of 19 studies around planetarium efficacy. A review of research around the use of remote telescopes was provided by Gomez and Fitzgerald (2017). Most recently, Brock, Prather, and Impey (2018) reviewed the literature on student understanding of cosmological time, while Cole, Cohen, Wilhelm, and Lindell (2018) reviewed studies related to spatial thinking and astronomy topics.

3. AER Researchers

Who conducts astronomy education research? There is a wide variety of people whose research may fall under AER, ranging from education researchers (most commonly those from science education or educational psychology) to astronomers who have dabbled in or shifted to an education focus to researchers who have created AER programs within their doctoral studies. Bailey and Lombardi (2015) described this variety with the help of a figure that mapped several well-known AE researchers' education degrees, work experience (e.g., teaching positions), and publications versus the same within astronomy.

4. Publishing AER

One of the challenges of identifying AER is the broad publishing landscape. This has undergone dramatic change over the last 50+ years (both within and beyond AER)

and can be demonstrated by looking back at the broad AER reviews described above. Of the 58 studies included in Wall's (1973) review, only a handful were published in three peer-reviewed journals (*Science Education*, *School Science & Mathematics*, and *Journal of Research in Science Teaching*); the majority were doctoral dissertations and Masters' theses. The AER-1 Resource Letter (Bailey & Slater, 2005) included those same journals plus 26 additional peer-reviewed journals, as well as conference proceedings and graduate projects (i.e., dissertations or theses). Lelliott and Rollnick (2010) included a further 22 journals not found in the prior reviews.

5. AER Journals

Many of the journals included in these reviews cover broad science education topics. However, there have been a few astronomy education-focused journals. Several described here are open-access, meaning that the articles are available free of charge to anyone with access to the Internet. The first, *Astronomy Education Review*, was published from 2001-2013 with one or two issues per year. Although no longer active, the journal's contents are archived in the digital repository Portico¹. The *Journal and Review of Astronomy Education and Outreach* was published for only two years but archives can be found online².

There are two AER journals currently in active publication. *Revista Latino-Americana de Educação em Astronomia (Latin-American Journal of Astronomy Education)*³ publishes two issues per year since its inception in 2004. All articles are published with abstracts in three languages—English, Portuguese, and Spanish—with the article then published in one of the three (the majority of which have been in Portuguese; P. Bretones, personal communication, September 2019). The *Journal of Astronomy & Earth Sciences Education*⁴, published since 2015, puts forth two issues per year. This journal charges an article processing charge (APC) to the authors to support the open-access availability.

6. AER in Physical Review

Although not specific to AER, *Physical Review Physics Education Research* (PRPER) has been the home to a number of astronomy-related publications in recent years. PRPER is an open-access journal that includes an APC and publishes two issues a year since its inception in 2005 (articles are posted as soon as they are through the complete review and publishing process). In June 2018, PRPER published a Focused Collection (i.e., special issue) on AER.

The AER Focused Collection was conceptualized in the spring of 2016 and approved by the Editorial Board in June of that year, with myself and Julia Plummer serving as guest co-editors. A call for papers⁵ was published on the PRPER website on 12 August 2016, with the call being circulated widely through relevant listservs and direct emails. Proposals of 500 words were due at the end of October 2016. We received 51 proposals, about twice as many as anticipated when the original issue proposal was developed. The two co-editors and two out of a five-member advisory board reviewed each proposal, with one of three decisions made: invite submission (16 proposals), invite with reservation (11 proposals), or decline submission (24 proposals). Full manuscripts were due 15 May 2017; 19 were received and underwent a full peer-review process in the same manner as any other manuscript received by the journal. The review and revision process yielded 14 published articles⁶ released on 15 June 2018.

The Focused Collection included 2 review articles and 12 empirical articles. Of the latter, five were quantitative studies, four were qualitative, and three used mixed methods. Published topics included spatio-temporal issues; astronomer-educator part-

1 https://access.portico.org/Portico/#!journalLOVIView/cs=IS-SN_15391515?ct=E-Journal%20Content

2 <http://www.toteachthestars.net/JRAEO/>

3 <http://www.relea.ufscar.br/index.php/relea>

4 <https://clutejournals.com/index.php/JAESE>

5 <http://link.aps.org/doi/10.1103/PhysRevPhysEducRes.12.020002>

6 <https://journals.aps.org/prper/collections/astronomy-education-research>

nerships; content understanding; instructional strategies; science literacy/nature of science; and gender issues in astronomy. Although this is a robust mix of topics, the list from the manuscript proposals goes even further to include teacher professional development; authentic inquiry; student learning outcomes; assessment and instrument development; citizen science; outreach program efficacy and outcomes; scale and distance; software and online resources; project-based learning; and more.

7. Future Directions

There are a number of exciting developments in AER that are taking place at the time of this first IAU Conference on Astronomy Education. This conference itself was the first of its kind. The closest in the past has been the Astronomical Society of the Pacific's Education and Public Outreach conferences, but they do not have as much international participation as could be expected from an IAU conference. AER is also regularly presented in sessions at the IAU General Assembly, American Astronomical Society, and American Association of Physics Teachers conferences.

8. Upcoming Works of Interest

Two books on astronomy education, edited by Chris Impey, Sanlyn Buxner, and Matthew Wenger, are being published by IOP Publishing in association with the American Astronomical Society. The first, *Astronomy Education Volume 1: Evidence Based Instruction for Introductory Courses*, was released in late November 2019. Chapters include topics such as learner-centered teaching; lecture-tutorials; interactive simulations; planetarium in astronomy instruction; authentic research experiences; research-based assessment tools; and inclusive astronomy; each chapter has a different author or author team that include many experienced astronomy education researchers. *Astronomy Education Volume 2: Best Practices for Online Learning Environments* is expected in early 2020 and likewise each chapter is authored by an individual or team with notable experience with online design and instruction.

A second project of interest is the inclusion of astronomy in an interdisciplinary project called "The Curious Case of Active Learning," led by Doug Lombardi and Thomas Shipley. Teams of discipline-based education researchers from astronomy, biology, chemistry, engineering, geography, geoscience, and physics education wrote white papers that then contributed to an overall review of the meaning and implementation of active learning in undergraduate science and engineering courses. In the case of astronomy, active learning is typically considered anything that gets students working independently or in small collaborative groups (of 2-6 students) to learn or reinforce content (Bailey, Prather, & Bretones, 2019). Strategies typically used in astronomy include think-pair-share and Peer Instruction; lecture-tutorials and ranking tasks; simulations; remote telescopes and authentic research; cooperative learning activities, laboratories, and flipped classrooms; and mixing any number of approaches from this list (i.e., using more than one of these in a given course). The manuscript that developed from this project is under review at the time of the submission of this conference proceedings (D. Lombardi, personal communication, 15 November 2019).

A third area of interest is work done by the American Astronomical Society's Education Committee. In 2018, the committee began offering an Education and Professional Development small grants project, wherein US-based AAS members could apply "to provide education-related mentoring and professional-development experiences for fellow members" (American Astronomical Society, 2019). Additionally, the Education Committee is in the early stages of a project to better understand the curriculum, both existing and needed, for undergraduate astronomy majors. A January 2020 Forum at the AAS meeting will kick this project off.

7 <https://www.iau.org/education/oae/>

Finally, the IAU's Office of Education (OAE) is under development and in late November 2019 announced where it will be physically located (Haus der Astronomie, an astronomy outreach center based in Heidelberg, Germany). The OAE is intended to support the education goals of the IAU Strategic Plan 2020-2030⁷.

9. Directions for Future Research

Based on this overview of AER and my own knowledge of both the AER field and the larger science education research base, I recommend a number of considerations for future research, both methodological and topical. Traditionally our work has been designed for quantitative methods—this is understandable, as most scientists are quite comfortable with quantitative measurement and reporting. However, we can and should continue to expand our use of more robust quantitative analyses. Gone are the days when t-tests of Hake's gain (Hake, 1998) are sufficient; instead, modern educational research is using analyses such as item response theory (see, for example, Wallace & Bailey, 2010) or multi-level modeling. At the same time, by welcoming an increased use of qualitative and mixed methods approaches, we can expand the breadth and depth of our research questions. Longitudinal studies, though challenging to manage, would also help move the field forward.

International collaborations can also help us expand AER. Much existing AER is based upon US students, often at the college level, at least insofar as works published in English. Collaborations can allow researchers to determine the commonalities and variances across different cultural and curricular backgrounds. New topics are also needed within AER, including but not limited to spatial thinking in astronomy, motivation and related constructs, and understanding of how visualizations and simulations can enhance learning.

These future directions build upon the exciting developments within AER over the last several years. An increasing robustness of research has been noted, particularly where the researchers can draw upon both AER literature and that of other fields such as science education or educational psychology. The IAU conference for which this proceedings article is written was, as noted earlier, the first of its kind and had capacity registrations. A number of AER-related talks were given at this conference. Finally, there is a new cohesion and a number of emerging leaders within the community, which is exciting to see.

10. Outstanding Questions

Any good research project—or review of many—should leave us with new questions to investigate, and so this paper ends with three potential questions for our consideration. First, how can we build upon existing work in other disciplines (e.g., education, cognitive science, physics education) to expand our impact? This is a true challenge because the literature base can quickly become overwhelming. Collaborations with researchers in these field could help make such efforts manageable, and through both the research design and implementation process and the publication of the results can help members of the AER community better understand the nature of research outside of our own world.

Collaboration—whether interdisciplinary or international—can be a challenge. How can we best support the community of astronomy education researchers, particularly our junior members? Conferences such as this one help, as do publication venues with rigorous review processes and a wide reach. An understanding of the role AER plays in promotion and tenure processes for faculty, or related processes outside of traditional academic positions, is also needed—this may require educating our astronomy colleagues on the value of AER.

The final outstanding question is related, but one which warrants its own focus: How can we recruit a greater diversity into the community doing AER and into the communities of learners it impacts? The inclusion of a wider variety of voices, whether that diversity comes from gender, ethnicity, home country, sexual orientation, or something else, will help us better understand the full spectrum of astronomy learning, paralleling the expansion of our understanding of the Universe as we developed tools that allowed us to “see” outside of the visible range.

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References

- Agan, L., & Sneider, C. I. (2004). Learning about the Earth’s shape and gravity: A guide for teachers and curriculum developers. *Astronomy Education Review*, 2(2), 90–117. doi:10.3847/AER2003017
- Albanese, A., Danhoni Neves, M. C., & Vicentini, M. (1997). Models in science and in education: A critical review of research on students’ ideas about the Earth and its place in the Universe. *Science & Education*, 6, 573–590.
- American Astronomical Society. (2019). AAS-epd mini-grant program. Retrieved 29 November, 2019, from <https://aas.org/education/aas-epd-mini-grant-program>
- Bailey, J. M., & Lombardi, D. (2015). Blazing the trail for astronomy education research. *Journal of Astronomy and Earth Science Education*, 2(2), 77–87. doi:10.19030/jaese.v2i2.9512
- Bailey, J. M., Prather, E. E., & Bretones, P. S. (2019). PSPI white paper: Active learning in undergraduate astronomy. Philadelphia, PA: Temple University.
- Bailey, J. M., Prather, E. E., & Slater, T. F. (2004). Reflecting on the history of astronomy education research to plan for the future. *Advances in Space Research*, 34(10), 2136–2144. doi:10.1016/j.asr.2003.01.038
- Bailey, J. M., & Slater, T. F. (2003). A review of astronomy education research. *Astronomy Education Review*, 2(2), 20–45. doi:10.3847/AER2003015
- Bailey, J. M., & Slater, T. F. (2005). Resource letter AER-1: Astronomy education research. *American Journal of Physics*, 73(8), 677–685. doi:10.1119/1.1949630
- Brazell, B. D., & Espinoza, S. (2009). Meta-analysis of planetarium efficacy research. *Astronomy Education Review*, 8(1), 010108-010101–010108-010111. doi:10.3847/AER2009033
- Brock, L. S., Prather, E., & Impey, C. (2018). Finding the time: Exploring a new perspective on students’ perceptions of cosmological time and efforts to improve temporal frameworks in astronomy. *Physical Review Physics Education Research*, 14(1), 010138. doi:10.1103/PhysRevPhysEducRes.14.010138
- Cole, M., Cohen, C., Wilhelm, J., & Lindell, R. (2018). Spatial thinking in astronomy education research. *Physical Review Physics Education Research*, 14(1), 010139. doi:10.1103/PhysRevPhysEducRes.14.010139
- Gomez, E. L., & Fitzgerald, M. T. (2017). Robotic telescopes in education. *Astronomical Review*, 13(1), 28–68. doi:10.1080/21672857.2017.1303264

- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64-74. doi:10.1119/1.18809
- Kavanagh, C., & Sneider, C. I. (2007a). Learning about gravity I. Free fall: A guide for teachers and curriculum developers. *Astronomy Education Review*, 5(2), 21-53. doi:10.3847/AER2006018
- Kavanagh, C., & Sneider, C. I. (2007b). Learning about gravity II. Trajectories and orbits: A guide for teachers and curriculum developers. *Astronomy Education Review*, 5(2), 53-102. doi:10.3847/AER2006019
- Lelliott, A., & Rollnick, M. (2010). Big ideas: A review of astronomy education research 1974–2008. *International Journal of Science Education*, 32(13), 1771-1799. doi:10.1080/09500690903214546
- Wall, C. A. (1973). A review of research related to astronomy education. *School Science and Mathematics*, 73(8), 653-669.
- Wallace, C. S., & Bailey, J. M. (2010). Do concept inventories actually measure anything? *Astronomy Education Review*, 9(1), 010116. doi:10.3847/AER2010024

Astronomy education research in France: survey and analysis. Preliminary results

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Abstract

We have surveyed and analysed the production of studies related to astronomy education research in France. This survey shows that astronomy education is a relatively new and sparse field in France, the first documents found dates from the late 1970's. Besides, while the first works focussed clearly on the practical pedagogical aspects, recent research rather deal with developmental psychology and science education. We have also noticed that the void left by the official bodies (Ministry of Education and its regional and local representatives, Universities) has been filled by initiatives from non-profit associations that have produced a wealth of resources and unpublished studies.

1. Introduction

Papers dealing with astronomy education are far from being equally distributed across the world. The international survey carried out by Bretones and Megid Neto (2011) shows a great disparity in the numbers and rates of publications depending on the country one considers.

In this paper, we aim at performing the same kind of work but at the French national level. According to Bretones and Megid Neto (2011), 13 papers on astronomy education were presented by French scientists at IAU meetings over the time-period 1988-2006. This production makes France the 4th highest contributor with 4.6% of the production. Yet, given the size of the astronomical community and the number of science didacticians or education specialists in a broader sense, this amount of publications appears slim.

National state-of-the-art in astronomy education at the French national level dates back from 2003 following a workshop on the subject (Merle and Girault, 2003) but to authors' knowledge, there has not been any study or even a workshop devoted to the subject ever since.

Our on-going study, which is only partly presented here, has four main goals:

- To survey and make available all works relevant to Astronomy Education Research (AER) in France.
- To analyse what has been done so far (who did what, where and how?)
- To find out whether past or current works are adapted to present problematics and curricula so we can plan for future work and aim at feeling gaps (Bailey, 2004).
- To make recommendations to French education authorities.

2. Methodology

2.1 Surveying the research papers and theses

We have looked for all kind of works that deal with astronomy education, in various disciplines (didactics, developmental psychology, etc.) and in various forms (peer-reviewed national and international papers, Master and Doctoral theses, etc.). By astronomy education, we mean works that are about astronomy education, not directly for astronomy education. In particular, pedagogical materials are not listed or surveyed here.

In practice, we have first searched for publications through the web, using search engines, with keywords such as “astronomy education”, “didactics of astronomy”, “pedagogy of astronomy”, etc. As a second step, we have consulted on-line archives like theses.fr and the IAU archive. Eventually, we have contacted the French astronomical and teaching communities.

We have met – and still meet – some difficulties in obtaining an extensive survey. One reason is that all PhD theses are not referenced and archived, which is particularly true for those defended before the 1990's. Masters theses are not referenced nor archived at all so if some are found, it is just thanks to their authors who have made them available on line. At last, older articles, which have never been digitalised, cannot be found easily.

2.2 Categorising the works

We have identified several kinds of work, various sources and different goals.

First, we have regrouped the publications by their source. We have identified several categories: papers in international peer-reviewed journals (in English); papers in national journals (in French); conference proceedings, PhD, habilitation and Masters theses; and other publications (e.g., press articles and reports).

Second, we have searched what focus the authors were seeking: how astronomy is taught (didactics), how it is understood and learnt (developmental psychology) or studies or documents about teachers training. This part is not yet completed.

Third and last what school levels or ages the studies focus on. The reader should note that this part may require the thorough reading of the studies as this information is not always explicit in the title or abstract. Therefore, this part is still under investigation and we will not present nor discuss it here.

3. Results

3.1 Categories of works

Quantitatively, all together, we found 115 publications, which is rather small compared to other works in general physics education or mathematics education for instance. The distribution according to their source is shown in Table 1.

Table 1: Distribution of all publications sorted by their sources

| | |
|--|----|
| Papers in national journals | 36 |
| Peer-reviewed papers in international journals | 23 |
| Proceedings | 32 |
| Master theses | 9 |
| PhD theses | 13 |
| Other publications | 2 |

Regarding the main aim of some of the published works (on-going analysis), the results is given in Table 2.

Table 2: Aim of the published works

| | |
|-------------------|----|
| Teaching | 42 |
| Understanding | 23 |
| Teachers training | 8 |

3.2 Geographical distribution

Based on the first author of each published work, we can draw the conclusions that there are, or have been, four main poles of work dedicated to AER. Sorted by decreasing number of publications: Paris, Toulouse, Montpellier and Lille.

Interestingly enough, most of the works found are published by a limited number of researchers. For instance, the 23 papers published in peer-reviewed journals were written by only 7 different first authors. Worse, if one takes into account all co-authors, it appears that only 4 teams have produced all 23 papers. Likewise, the 32 proceedings were written by 12 different first authors, belonging to 9 distinct teams or individuals. One has to realise that those teams have not been active at the same time, their activities were spread over the years. At a given time, only two or three groups of individuals have worked on AER. This shows how limited and fragile the AER community in France is.

3.3 Evolution

Figure 1 shows the time distribution of all published works. One can see that AER really took off in the early 1990's. There have been ups and downs over the years, the ups corresponding to IAU meetings or national conference that led to the publication of proceedings. (This is the case in 2003 when a national meeting focusing on astronomy education was organised and a book subsequently issued.)

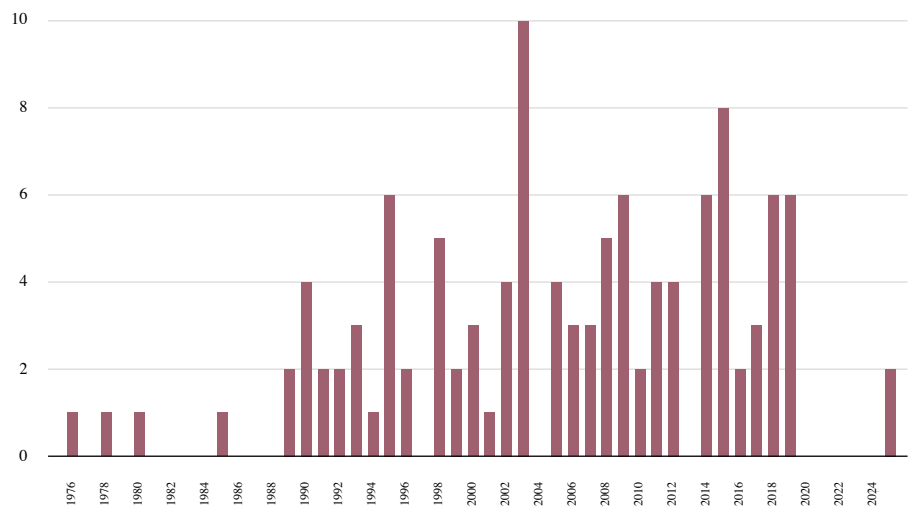


Figure 1: All publications relevant to AER in France found in the time period 1976-2019. The two publications marked as published in 2025 are on-going PhD theses.

If sorted by sources of publication, the temporal distributions are given in Figure 2 (articles and proceedings) and Figure 3 (theses). Figure 2 shows a clear change in habit: publications in peer-reviewed journals peak up around the year 2006. This corresponds to the beginning of the activities of the group of developmental psychology in Toulouse. In fact, the Toulouse team have written most of the papers published in

peer-reviewed journals: they are involved in 16 out of the 20 papers published in peer-reviewed journals as of 2006! Even considering all sorts of publications, one can see a change of trend: works focussing on didactics (how astronomy is taught) has left the room to works on developmental psychology (how astronomy is understood). However, we experience a revival in didactics of astronomy with a new chair recently opened at Cergy-Pontoise University.

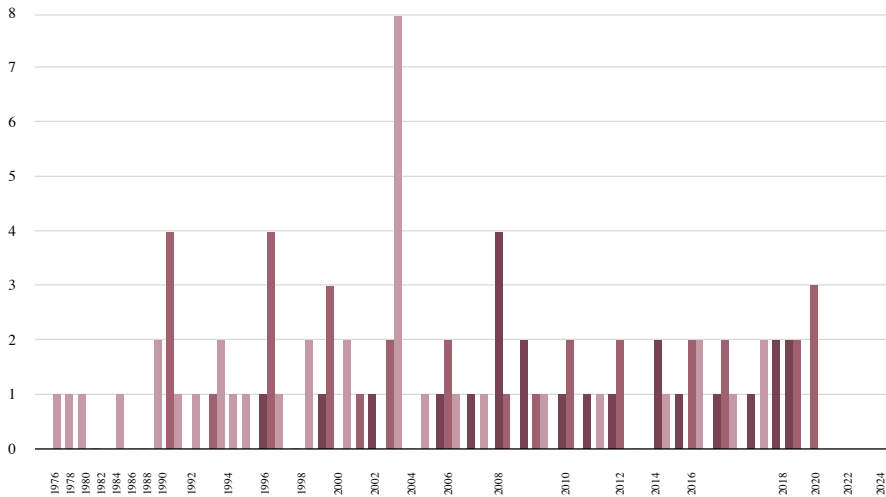


Figure 2: Articles published in peer-reviewed journals (blue), proceedings (orange), and national journals (grey) found in the time period 1976 – 2019.

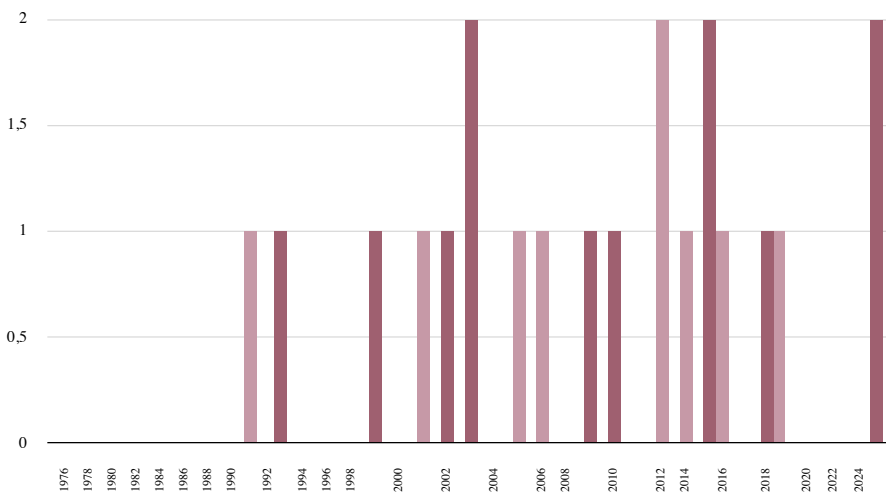


Figure 3: PhD (blue) and Masters (orange) theses defended, or to be defended (the latter are arbitrarily dated year 2025) found in the time period 1976 – 2019.

4. Discussion and suggested tracks for future research

4.1 Curricula in France

There are no dedicated astronomy courses in primary or secondary school, but astronomy is partly addressed in general science at primary school; and in physics, natural science, and mathematics at secondary school. With little imagination and good will, astronomy can be tackled in history, language, philosophy, art, etc. There are many available resources through the website of the ministry of education (Eduscol) or through publications of professional associations (union of physics and chemistry teachers, union of mathematics teachers, committee for links between astronomers and teachers, etc.)

Since September 2019, high schools must apply new curricula. In particular, sciences are taught as a whole for all students. This implies that teachers of different disciplines (math, physics, biology, etc.) have to collaborate and prepare courses together. As far as astronomy is concerned, the shape and motion of the Earth, which involve scientific method and critical thinking, information and media literacy, and history of science and epistemology are involved. One of the goals of this new approach is to combat the propagation of fake news. It is an interesting approach but teachers are not trained for this and often feel helpless. Besides, although this approach makes sense, no study really demonstrated that it will be fruitful.

4.2 On the role of non-formal education

Most of the astronomy education is done by clubs and non-profit associations (ca. 900 listed by the French astronomy association, AFA), science centres and museums (ca. 200 listed by AMCSTI, the science centres and museums association), or planetariums (ca. 75 fixed and ca. 110 wandering). Most of the wandering planetariums are used in schools by visiting associations. Beyond the general public, some associations have specific targets: teachers for F-HOU (Ferlet and Melchior, 2005) or CLEA (Pitout, 2020), detained public in jails or hospitals, sensory impaired, etc.

5. Summary and concluding remarks

AER in France has had ups and downs depending on the interest of very few individuals. From mid 2000s, more papers published in peer-reviewed journals. Research activities have been concentrated in a few active clusters (Paris, Montpellier, Lille and Toulouse).

There is a clear revival these days with – at least – two very active and complementary groups: developmental psychology in Toulouse (learning) and didactics in Paris (teaching).

If we should make recommendations (Slater, 2008), we would state that promoting astronomy is an excellent cross-disciplinary subject. In addition, fake news and conspiracy theories in astronomy and space science (flat Earth, Man never been on the Moon) may be used in a positive way and astronomy education may surely help combat those, but a proper and ambitious pre – and in-service teacher education plan must be initiated (Frède, 2006; 2008). The country needs studies and evaluations to assess the effectiveness of the new science curricula involving astronomy.

References

- Bailey, J. M., Prather, E. E., and Slater, T. F. (2004), Reflecting on the History of Astronomy Education Research to Plan for the Future, *Advances in Space Research*, 34, 2136.
- Bretones, P.S. and J.M. Neto (2011), An Analysis of Papers on Astronomy Education in Proceedings of IAU Meetings from 1988 to 2006, *Astronomy Education Review*, 10, 010102-1, doi: 10.3847/AER2010010.
- Ferlet, R. and A.-L. Melchior (2005), F-HOU: L'Univers à portée de main HOU-Europe. *International Amateur-Professional Photoelectric Photometry Communications*. 39-43.
- Frède, V. (2006), Pre-service elementary teacher's conceptions about astronomy, *Advances in Space Research*, 38(10), 2237-2246.
- Frède, V. (2008), Teaching astronomy for pre-service elementary teachers: A comparison of methods, *Advances in Space Research*, 42(11), 1819-1830.
- Merle, H. and Girault (2003), L'enseignement de l'astronomie, ASTER 36, INRP.
- Pitout, F. and C. Ferrari, (2020) CLEA, a French pro-am initiative to foster astronomy education, this issue.
- Slater, T. F. (2008), The First Big Wave of Astronomy Education Research Dissertations and Some Directions for Future Research Efforts, *Astronomy Education Review*, 7, 1.

Literature review of Master and Doctoral thesis in Astronomy Education in Portugal: overview, progresses and setbacks

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Abstract

We present the major findings of the work developed until now towards a fine-grain content analysis of Master and Doctoral thesis in Astronomy Education published in Portugal. The categories were the same used by one of us in previous state-of-the-art research, that is: year of publication, institution, type of the thesis (doctoral or master), school grade level, focus of the study and type of academic research. Here we focus on the first three categories. We identified a total of 116 theses, with only two Doctoral dissertations. University of Porto was the institution from which came the majority of thesis in the field with 79 (68.1%). As an average, this figure is misleading for it does not represent the trends in later years of this study. In total there was fifteen University and Polytechnic institutions in Portugal conferring the degree but seven of them only contributed with one thesis. Finally we briefly discuss some factors that explain this distribution and present a brief comparative analysis between the periods 1999 to 2003 and 2010 to 2016 from which we have all the thesis available and analyzed according to the above mentioned categories.

Keywords

Astronomy Education; Literature review; Astronomy in Portugal

1. Introduction

This work presents the current knowledge we have had obtained of the state-of-the-art concerning Astronomy Education in Portugal as seen through academic thesis presented to get the degree of Master or Doctor. Far from being a final assessment

of the production of Master and Doctoral dissertations completed in Portugal in this field, we present an overview of the findings at present stage and advance with some discussions and inferences.

The context in which our work begun and developed is the worldwide effort under the C1 WG Theory and Methods umbrella to know what was produced in Astronomy education (Paulo S. Bretones & Neto, 2012).

Until not long ago Astronomy education research has had been scattered in several fields each of which reported their advances in different reviews and conferences (Bailey, 2011). An effort to asses how, in what directions, where and with what impacts Astronomy education evolved has been done by several authors (Bailey, 2011; Bailey & Lombardi, 2015; Bailey, Prather, & Slater, 2004; Bailey & Slater, 2003, 2005; Bishop, 1977; Bretones, 2019; Bretones & Neto, 2012; Fraknoi, 2015; Lelliott & Rollnick, 2010; Wall, 1973).

This scattering of the Astronomy education research is changing but it is to expect that the intersection of the field with physics education, geology education and more recently with biology education and others does not contribute to a more definitive autonomy of the Astronomy education research field. This is not necessarily bad or good in its own but put some challenges to the formation and progress of the discipline. Namely, Astronomy education research should strive to meet the standards and ethos of education research construed more broadly.

Next, we briefly outline our methodology after which we present the results and discuss them. Finally, are presented some indications related to future work

2. Methodology

This study is a literature review using an interpretative analysis of exploratory character (Creswell, 2003; Neto, 2011; Silveira & Córdova, 2009). The corpus of our study is comprised by 116 Master and Doctoral theses completed and published in the repositories or in post-graduate University web pages in Portuguese Universities until 2016. Beyond the Thesis on Astronomy Education, closely related thesis in its content such as Communication in Astronomy, Curricular development, and Mathematic education were also searched. Plus, the corpus of the research also includes thesis that are professional in its nature and not academic as traditionally understood. Those theses are the “Professional Masters” obtained by pre-service teachers to get the teachers’ certificate. The professional masters have a component of apprenticeship report after which follow a research part; was this research part that we analyze to assign, or not, the master’s degree to the corpus of this review.

A full search on the Open Access Scientific Repositories in Portugal (RCAAP) and in the Repositorium of each University and Polytechnic Institute with the keywords of Astronomy, space, education, Sun, Moon, stars, planet, learning, teaching, or some combination of them. Also, after identified some discrepancies between the thesis in the repositories and some listed in post graduate courses in Astronomy education, we explored specific pages of those courses which gave some more thesis. In the end we have a total of 116 thesis.

To perform the literature review we used the categories defined by Bretones (2011): year of production, institution, degree (Master or Doctoral thesis), intended scholar year, focus, type of research and methodology. At this stage we are only in conditions to give a complete account of the first three categories and provide a preliminary discussion on other two categories, the intended scholar year and focus of the thesis.

3. Results and Discussion

The 116 theses are distributed between 1999 and 2016 according to Figure 1.

As one outcome of the pioneering efforts of Professor Teresa Lago with the creation of the first undergraduate course in Astronomy in Portugal at University of Porto in 1987 and the first Graduate Program in Astronomy Education in Portugal in 1997 (Da Costa, 1990; Lago, 1990) the first master thesis began to appear in 1999 (4 theses) and the production step up until 2003 (12 theses) with a brief decline in 2002. In 2001 the Introduction of elementary Astronomy in the 7th grade constitute another factor to increase the need of studies in Astronomy education. Also, with the International Year of Astronomy in 2009 which was coincident with the creation of the European space of education (Bologna process) had effects in subsequent production of theses in the field.

Of the total 116 theses only two are Doctoral dissertations: one doctoral thesis was completed at University of Aveiro in 2014 and the other at University of Coimbra in 2015.

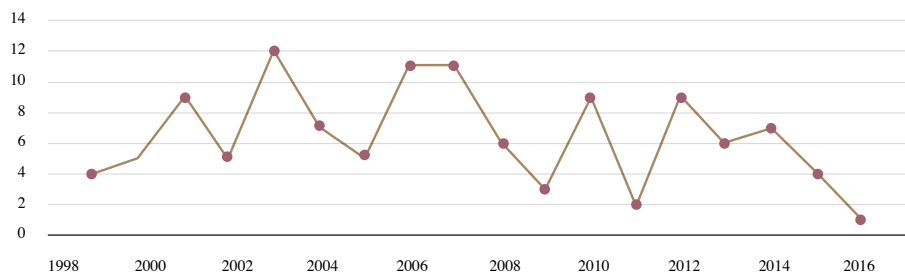


Figure 1. Production of Master and Doctoral Thesis in Portugal until 2016.

Regarding the Institutions involved (Figure 2) there is a huge gap in production between University of Porto with 79 thesis and all the others with the remaining 37. This data is a powerful evidence on the relation between the development of research in a field and the institutional development necessary to that development.

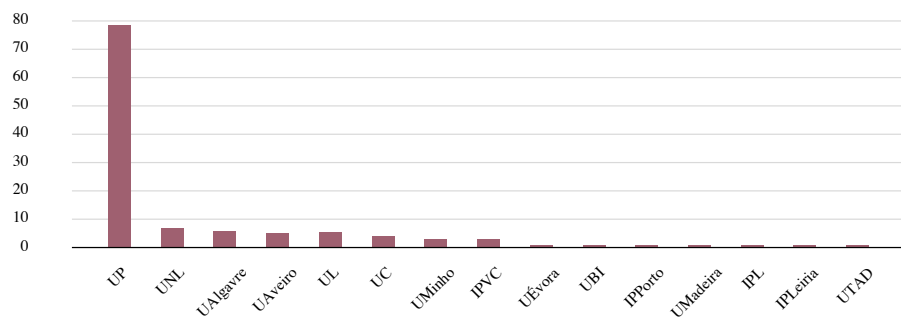


Figure 2. Distribution of Master and Doctoral theses by Portuguese University Institutes.

Until 2010, of the 78 theses University of Porto contributed with 68 (87%%). In that span of time only two other Universities contributed with one thesis each: University of Algarve in 2003 and University of Aveiro in 2005. Between 2011 and 2016 that changed with only 11 (28,2%) of the theses coming from University of Porto (Figure 3).

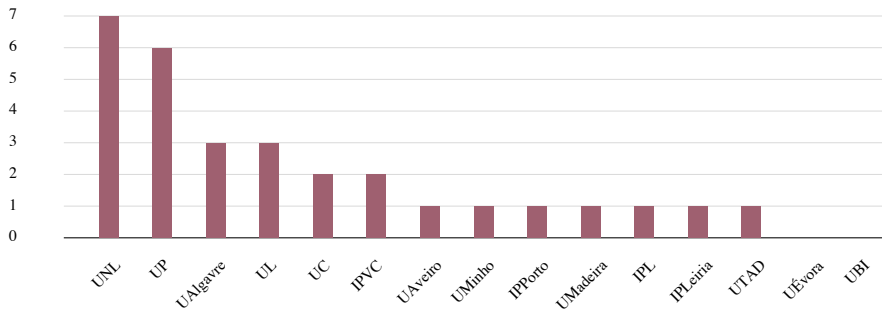


Figure 3. Distribution of thesis by institution after 2011.

After the 2009 International Astronomic Year, there was more theses produced in more institutions. If the activities of the 2009 IAY was certainly a factor, the Bologna process and the emergence of elementary astronomy in the curriculum in early years was certainly other factors that contribute to this spread among institutions. Namely, the training of elementary teachers that is done at the Polytechnics (In Portugal the Polytechnic branch of the University System don't offer the Doctor degree and is more professional oriented) assisted to an interest in master thesis related to Astronomy education since early years of schooling. Other two fields needing research in Astronomy education was the widespread of ICT on the one hand and of Science Centers on the other.

Since we have had access to all the thesis in the periods 1999 to 2003 (period 1) and 2010 to 2016 (period 2), we present the result of a content analysis related to the other categories, that is, type, methodology (presence or not), focus and level (Table 1) . planetariums, etc.). Finally, regarding school level, the intended target of period 1 are college education, secondary education (mainly) and basic education (7 grade). In period 2 pre-school and primary school (6/7 to 11/12 years old) are the main targets.

Table 1. Characterization of Astronomy Education theses related to four categories: Type, Methodology (presence or absence), Focus and Level.

| | 1999 – 2003 | 2010 – 2016 |
|--------------------|---|---|
| Type | Theoretical essays | Educational experiences (research on practice etc.) and empirical research |
| Methodology | Absent | Defined in more than half of the theses |
| Focus | Teaching Materials; Teacher training | Teaching and learning; curricular discussions and understanding of teachers and students; non-formal environments (centres of science, planetariums etc.) |
| Level | College education, secondary education (mainly) and basic education (7 grade) | Pre-school, elementary education (6yo to 11yo) and 7 grade |

References

- Bailey, J. M. (2011). Astronomy Education Research: Developmental History of the Field and Summary of the Literature. [a commissioned paper for the National Research Council's Committee on the Status, Contributions, and Future Direction of Discipline-Based Education Research (DBER)]. National Academies Press. Retrieved from https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_168276.pdf
- Bailey, J. M., & Lombardi, D. (2015). Blazing The Trail For Astronomy Education Research. *Journal of Astronomy & Earth Sciences Education*, 2(2), 77. <https://doi.org/10.19030/jaese.v2i2.9512>
- Bailey, J. M., Prather, E. E., & Slater, T. F. (2004). Reflecting on the history of astronomy education research to plan for the future. *Advances in Space Research*, 34(10), 2136–2144. <https://doi.org/https://doi.org/10.1016/j.asr.2003.01.038>
- Bailey, J. M., & Slater, T. F. (2003). A Review of Astronomy Education Research. *Astronomy Education Review*, 2(2), 20. <https://doi.org/10.3847/AER2003015>
- Bailey, J. M., & Slater, T. F. (2005). A Contemporary Review of K-16 Astronomy Education Research. *Highlights of Astronomy*, 13, 1029–1031. <https://doi.org/https://doi.org/10.1017/S1539299600018037>
- Bishop, J. E. (1977). United States Astronomy Education: Past, Present, and Future. *Science Education*, 61(3), 295–305. <https://doi.org/https://doi.org/10.1002/sce.3730610305>
- Bretones, Paulo S., & Neto, J. M. (2012). Astronomy Education Review. *Astronomy Education Review*, 11(1), 010108. <https://doi.org/10.3847/AER2012011>
- Bretones, Paulo S. (2019). Astronomy Education Research: Impact and Future Directions. *EPJ Web of Conferences*, 200(01022), 1–11. <https://doi.org/10.1051/epj-conf/201920001022>
- Bretones, Paulo Sergio. (2011). Banco de Teses e Dissertações Sobre Educação em Astronomia : Implantação , Dificuldades e Possíveis Contribuições. In I Simpósio Nacional de Educação em Astronomia (pp. 1–6). Rio de Janeiro: Sociedade Astronômica Brasileira. Retrieved from sab-astro.org.br/eventos/snea/i-snea/atas/comunicacoes-orais/co15/
- Da Costa, A. A. (1990). Astronomia em Portugal : O desenvolvimento necessário. *Gazeta de Física*, 13(1), 51–58. Retrieved from <https://www.spf.pt/magazines/GFIS/429/article/1387/pdf>
- Fraknoi, A. (2015). A Brief History Of Publishing Papers On Astronomy Education Research. *Journal of Astronomy & Earth Sciences Education (JAESE)*, 1(1), 37. <https://doi.org/10.19030/jaese.v1i1.9105>
- Lago, M. T. (1990). The Teaching of Astronomy at University Level in Portugal. *International Astronomical Union Colloquium*, 105, 26–28. <https://doi.org/10.1017/S0252921100086310>
- Lelliott, A., & Rollnick, M. (2010). Big Ideas: A review of astronomy education research 1974–2008. *International Journal of Science Education*, 32(13), 1771–1799. <https://doi.org/10.1080/09500690903214546>
- Wall, C. A. (1973). A Review of Research Related to Astronomy Education. *School Science and Mathematics*, 73(8), 653–669. <https://doi.org/https://doi.org/10.1111/j.1949-8594.1973.tb09135.x>

Female participation in theses on astronomy education in Brazil

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Abstract

This paper presents an overview of Brazilian astronomy education researches (AER) from theses and dissertations, analyzing the gender of authorship and investigating the female participation in this field. The database allows us to raise some questions about amount male and female participation in scientific production and about universities, gender of supervisor and type of academic production. The objective is to provide a view about female authorship in this area and reflect about the situation with lens of gender literature, especially the questions about women in science. With the support of literature related to the state-of-art research, the data were analyzed and organized according to the gender of the authors, from 1973 to 2017. With a total of 373 MSc and PhD theses, 136 (36,4%) were made by women, and 237 (63,4%) by male. From this survey, several elements emerge, reflecting on produced works and gender issues implied in the constitution of the astronomy education research area. The results also show trends in comparison with researches on female participation in other countries and in Astronomy. This study should encourage the participation of women in the Astronomy Education Research.

Keywords

State-of-art; Gender; Astronomy Education Research (AER), Women in Science; Theses; Brazil.

1. Introduction

This research arose from the curiosity to verify the gender balance in the authorship of works produced in postgraduate studies in Astronomy Education in Brazil. Provocative thinking is related to a perception that the area of Astronomy and Physics is generally male, just as the area of education is usually feminized. Thus, arises the curiosity to know how is the situation in the merge of these two different areas, in Astronomy Education Research (AER).

Gender studies have a spectrum of formats, one of which is the study with comparative characteristics (LETA, 2014). This is the most traditional in this field and seeks differences, similarities and relationships in the most diverse aspects, representations and conditions of existence between men and women. They are elementary to find differences, in different areas, and this is a way to see a panoramic overview and think about gender balance. In this paper we seek to present and discuss quantitative and historical data of the area in order to expose a panorama for reflections and problematizations.

We use the State-of-the-art researches, that are a genre that can assist in the process of organizing what has been produced in certain areas and indicates trends and gaps. In terms of Astronomy Education there are some works produced in this sense, in Brazil (BRETONES; MEGID NETO, 2005; BRETONES; MEGID NETO; CANALLE, 2006; MARRONE JR.; TREVISAN, 2009; IACHEL; NARDI, 2010; BRETONES; ORTELAN, 2012; ORTELAN; BRETONES, 2012; BUSSI; BRETONES, 2013; FERNANDES; NARDI, 2015; SIMON; BRETONES, 2018) and in others countries (WALL, 1973; BAILEY; PRATHER; SLATER, 2004; BAILEY; SLATER, 2004; SLATER, 2008; LELLIOTT; ROLLNICK, 2010; BRETONES; MEGID NETO, 2011; FRANKNOI, 2014; SALIMPOUR; FITZGERALD, 2018). According to Bailey, Prather and Slater (2004), Bailey and Slater (2004) and Slater (2008), these area analysis demonstrate a maturation of the field and raise questions to project the future.

The most part of works cited do not include analysis regarding the genre of authorship, with the exception of Simon and Bretones (2018) and Salimpour and Fitzgerald (2018), in which we consider to be important information from the point of view of discussing the presence of women in science area.

Regarding female participation in Brazilian astronomy, Viegas (1994, 2014a, 2014b) and Silva (2007) found that it is still small compared to male and compared to the percentage of women in Brazilian society. Thus, we seek to verify the current panorama of female participation in the academic production on Astronomy Education and how these data dialogue with what the authors verified in their work.

For this research, we only need to consider gender in binary form, because from the database we use, bibliographic, we can only consult the name and academic curriculum of the authors. Despite this, we recognize that there are other ways of looking at gender than just binary.

Considering this limitation, investigating this issue and verifying some numerical differences helps to discuss historical and social processes commonly naturalized, that are related to structures that foster the female condition in the face of our society androcentricly-based, especially in the sciences area.

2. Women in Science

According to Leta (2014), Gender Studies have emerged as a new field of knowledge in recent decades, in an interdisciplinary manner, having as its central themes the

representation and identity of men and women in society. In this field, it is possible to find Women's Studies, being one of the developed themes, women in science, whose focus is on women and their relationship with the sciences, was generally associated with the male and androcentric world.

Women are a minority in the scientific field, and depending on the area of science chosen, this difference may vary greatly, as in biology the difference is smaller than in physics (VIEGAS, 2014a). Research has shown that there is no justifiable difference in cognitive ability between men and women that can justify such a difference, therefore Viegas (2014a, p. 533) concludes that the disparity of female participation in certain areas should be considered a consequence anthropological and cultural. Leta (2014, p. 150) indicates that the idea of women as inferior in science still persists in the 21st century, although research shows similar performances.

The area of Astronomy in Brazil has grown considerably since the 1970s, and it is important to consider the founding of the Brazilian Astronomical Society (SAB) in 1974. We can see female participation in this scientific society for a few decades:

Table 1 – Members of the Brazilian Astronomical Society (SAB)

| Year | 1974 (VIEGAS, 2014a) | 1994 (SILVA, 2007) | 2004 (SILVA, 2007) | 2019 ⁸ |
|--------------|-------------------------|-----------------------|-----------------------|--------------------|
| Total | 48 | 227 | 479 | 738 |
| Women | 5 (10.4%) | 51 (22.5%) | 120 (25%) | 218 (29.5%) |
| Men | 43 (89.6%) | 176 (77.5%) | 359 (75%) | 520 (70.5%) |

⁸ Data provided by Brazilian Astronomical Society (SAB) secretariat by email in november 2019. The numbers just consider active members.

As we can see, since its inception, SAB has shown a small growth in relation to the female participation, but quite slow.

Silva (2007) also presents data in his article that show that there is a decrease as one ascends to an academic career. In none of the academic levels analyzed by the author the situation was close to be equitable and among the issues that possibly justify this difference are the greatest career dropout in relation to men, which also relates to family issues, where there are still situations that polarize the academic career and family formation, isolation, expressive lack of same-sex peers and discrimination. These factors increase underrepresentation and consequently reduce the incentive for new women to enter.

Regarding the female reduction in high positions, according to Vasconcellos and Brissola (2009, p. 218) the phenomenon "glass ceiling" is known in the gender literature in relation to the low female participation in more valued positions and of greater power and it is so called because of an almost invisible discriminatory mechanism that prevents women's career ascension. Thus, from the data presented, it is possible to verify that the master's degree shows a diminished female presence, that subtly worsens when we look at the percentages with regard to the doctorate.

From these data, we can think about the reasons for the low female participation in these scientific areas. According to the literature, we will point out some ahead.

According to Yannoulas, Vallejos and Lenarduzzi (2000), the discrimination is one cause and it is possible to distinguish at least three forms of **discrimination**: direct or manifest, indirect or hidden, and self-discrimination. The latter is a kind of internal surveillance and repression mechanism that forges desires, expectations “so that some educational or professional options become unthinkable and others strongly oriented or conditioned” (Yannoulas, Vallejos, Lenarduzzi, 2000, p. 428). Therefore, the presence / absence of women in different areas cannot be understood as natural.

Among the cultural and social aspects that influence career choices in adolescence, low female **representativeness** in the sciences is one of the causes pointed out in North American studies, according to Viegas (2014a, 537). In Brazil, this issue is analyzed from the perspective of isolation and encompasses as possibilities the woman be the only one in the classroom, a research group, or in conferences (Viegas, 2014a, 537), which can be a demotivating factor, even if unconscious.

There are also issues related to the constitution of family and career that are still factors that do not add up, but for cultural reasons, are yet opposed. The care with family of origin, the distribution of tasks, child care, still unequal, are conditioned especially to the figure of women (Viegas, 2014a; Silva, 2007). To demonstrate this situation there are data presented in Silva (2007) that show that, in the career of Brazilian astronomy, it was an option not to have children for about 32% of SAB’s partners, while in the Brazilian population the percentage of women without children is between 10 % and 11% (Viegas, 2014a, p. 538).

3. Methodology

This research is a State-of-the-art, research which works to assist in the process of organize what has been produced in certain areas and indicate trends and gaps. According to Megid Neto and Carvalho (2018), such works are very important to socialize and disseminate the results of an area that presents a considerable amount of productions, from the systematization, analysis and evaluation of this production. This type of research can be panoramic, in the sense of deeply analyzing an entire area, or focused on certain characteristics, as in our case, specifically focused on the gender issue of this area.

We follow the perspective of content analysis (Bardin, 2011) in this research. It is organized according to the three chronological poles, which includes pre-analysis, material exploration and treatment of results and, finally, inference and interpretation (Bardin, 2011).

Our data is composed by governmental databases available in our country CAPES (Coordination for the Improvement of Higher Education Personnel) and BDTD (Brazilian Digital Library of Theses and Dissertations) that brings together all papers done in post-graduation. We also have a special digital library of theses and dissertations just about astronomy education BTDEA (PhD and MSc archives on Astronomy Education) that we help to keep and feed with all this information.

In the pre-analysis, to delimit the corpus, we searched the bases cited with the combined keywords “astronomy and education” and “astronomy and teaching”. Our data is composed of theses and dissertations written in post-graduation programs in Brazil from 1973 to 2017 with a total of 373 papers, with 35 thesis from doctorate degree and 338 dissertations of master degree. Then, the exploration of the materials was developed and the results were treated, which were categorized using spreadsheets.

We did the data collection, organized and analyzed each thesis and dissertations using descriptors to classify them. That way we find the data gender participation. Our aim

was to verify the participation in authorship of women to analyze how the area has been built in Brazil.

We analyzed the authorship of each work and classify according to binary genre. In cases where there were questions about the authorship genre, the Lattes Platform was consulted, which is the basis of academic curriculum maintained by the National Research Council (CNPQ).

It is important to notify that in Brazil we use different words to talk about works written in masters or doctorate degrees. For doctor's degree we use theses and for master's degree we use dissertations and because of this we will use these two words to identify the type of degree.

The results will be presented and discussed below.

4. Results and Discussion

This Figure 1 shows us how Brazilian population is divided by gender:

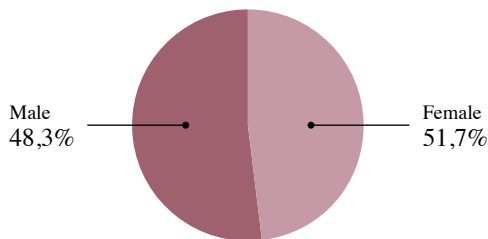


Figure 1: Authorship by gender

As we can see, in the last survey carried out by governmental institutions, in 2018, we have 51.7 % of women and 48.3% of men that compose our population. This is an important graph as it shows us a view of Brazilian society by gender. The next figure show us how all productions are divided, considering theses and dissertations.

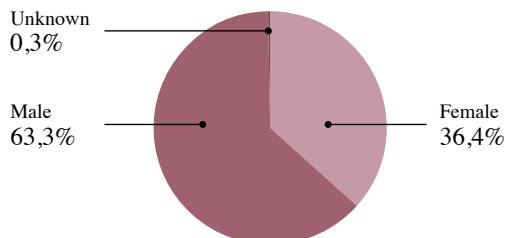


Figure 2: Authorship by gender

In Brazil, considering the period from 1973 to 2017, we have 373 postgraduate studies. Of these, 35 are doctoral theses and 338 master’s dissertations. All works could be classified by authorship genre, except for one, which will be identified as “unknown”. When we observe all the academic papers of post-graduation, we have 63.3% (236) of work with authorship by men, 36.4% (136) by women and 0.3% (1) unknown.

When we look at **different kinds of productions**, we can see that the numbers of doctorate theses is lower than dissertation of master’s degree. It’s a big difference between these levels of post graduate degrees.

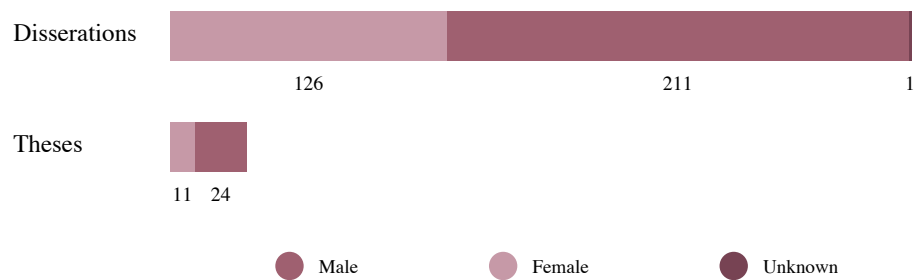


Figure 3: Authorship by gender

In the theses, we have 11 (31.4%) papers produced by women and 24 (68.5%) with male authorship, while in the dissertations we have 125 (37%) papers by female authors and 212 (62.7%) by men. And here we have also the one dissertation that we could not identify the authorship gender (0.3%)

Table 2: Historical timeline

| Year | Type/ gender | Name | Institucion/ Region |
|------|------------------------|------------------------------|---------------------|
| 1973 | 1ª Male Thesis | Rodolpho Caniato | Unesp / Southeast |
| 1986 | 1ª Male Dissertation | Marcos César Danhoni Neves | Unicamp/Southeast |
| 1990 | 1ª Female Dissertation | Silvania Sousa do Nascimento | USP / Southeast |
| 2006 | 1ª Female Thesis | Cristina Leite | USP / Southeast |

The Table 2 shows us a **historical timeline** of the first thesis and dissertations between male and female. As we can see, the first one was a thesis made by a man, in 1973. The first female thesis came just in 2006. About dissertation, the first with male authorship was in 1986 and the first female was in 1990.

Regarding these there was a huge difference of time. It is relevant to consider that there is a difference of 33 years between the first thesis (Caniato, 1973), which was of male authorship, until the defense of doctorate of Cristina Leite (2006). Note that Leite's thesis (2006) is defended 16 years after the first female authorship master's degree by Nascimento (1990).

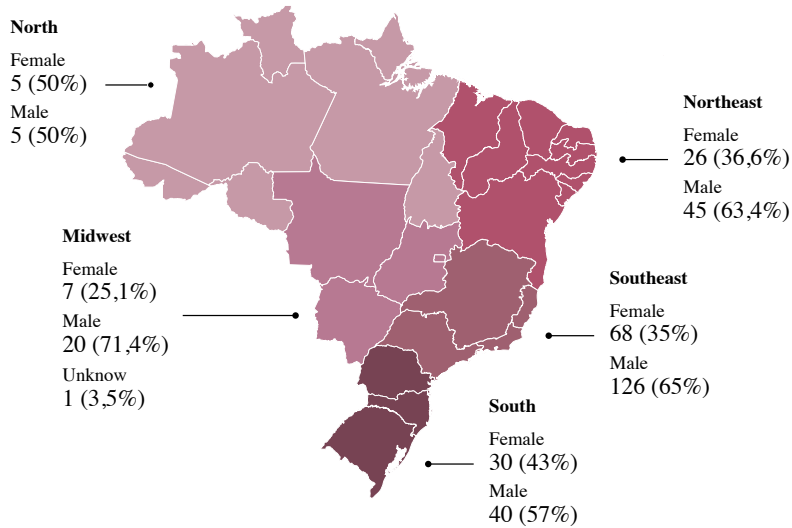


Figure 4: Authorship by gender and region of Brazil

The largest academic production considering the total number of papers is produced in the southeast region. In case of female authorship, we have firstly the southeast region, the south and then, the northeast. Considering the next table 3, about institutions, the northeast of the country has been a place that female participation has increased in post graduation in the astronomy education area recently.

Looking at the **institutions**, our postgraduate work is done by 81 different universities. Of these, 53 (65.4%) universities contain some female authorship production.

Table 3: Authorship by gender and region of Brazil

| Institutions – N | Female N (%) | Male N (%) | Time | Years |
|-----------------------|--------------|------------|-------------|-------|
| USP ⁹ – 53 | 20 (37.7%) | 33 (62.3%) | 1990 – 2017 | 27 |
| UEFS – 22 | 12 (54.5%) | 10 (45.5%) | 2015 – 2017 | 2 |
| UFRN – 15 | 8 (53.3%) | 7 (46.7%) | 2007 – 2016 | 9 |

⁹ The name of institutions: USP – Universidade de São Paulo; UEFS – Universidade Estadual de Feira de Santana; UFRN – Universidade Federal do Rio Grande do Norte; UNESP – Universidade Estadual Paulista; UNICSUL – Universidade Cruzeiro do Sul; UEL – Universidade Estadual de Londrina.

| | | | | |
|--------------|------------|-------------|-------------|----|
| UNESP – 23 | 8 (34.8%) | 15 (65.2%) | 1997 – 2017 | 20 |
| UNICSUL – 17 | 5 (29.4%) | 12 (70.6%) | 2006 – 2017 | 11 |
| UEL – 10 | 5 (50%) | 5 (50%) | 2005 – 2017 | 12 |
| Others – 233 | 78 (33.5%) | 154 (66.1%) | – | – |

These are the 6 universities with the most female authorship postgraduate academic papers. The others have less than 5 PhD written by women.

Analyzing the **gender of adviser**, we have the following situation:

Table 4: Gender of adviser

| Total Works | Total Adviser | Female | Male |
|-------------|---------------|------------|-------------|
| 373 | 244 | 75 (30.7%) | 169 (69.3%) |

Table 5: Gender of co-adviser

| Total Works | Total co-supervisor | Female | Male |
|-------------|---------------------|------------|------------|
| 63 | 49 | 17 (34.7%) | 32 (65.3%) |

Analyzing the tables 4 and 5 it is possible to verify that participation of women in adviser (30.7%) is lower than co-adviser (34.7%) and in both cases is low. When we include the female participation as adviser and co-adviser, we have only 92 (31.4%) cases.

The Figure 5 shows the academic papers listed by year of publication and genre of authorship. From this organization it is possible to compare the female presence in time scale in relation to male authorship, linearly to verify these differences, as well as to project possible traits in relation to the previous history, the current situation and the future.

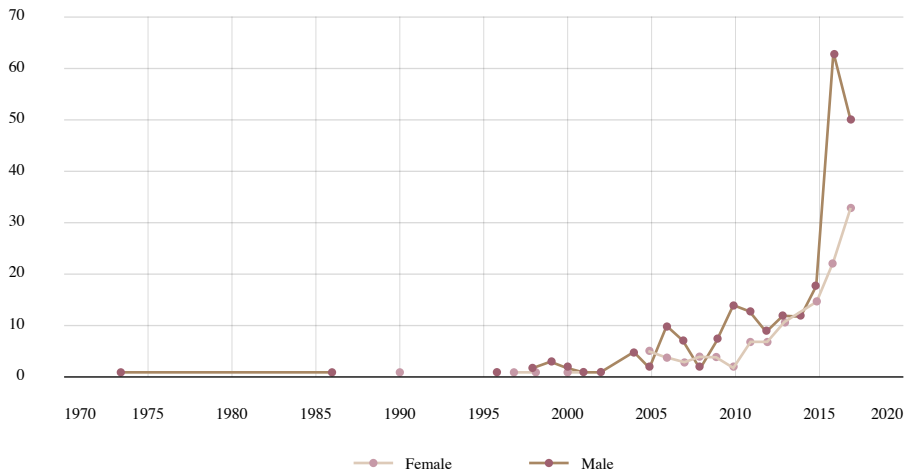


Figure 5: Authorship by gender and by year

The first thesis defended in Brazil in the field of Astronomy Education occurred in the 1970s (Caniato, 1973) and the growth of theses and dissertations is perceived in the 2000s. It is understood that this is a recent field, compared to other areas. The Figure 5 shows us even more significant growth in the last 4 years. This is due to the expansion of professional masters degrees, dedicated to acting teachers.

The projective line created from this organization shows that female participation is recent, growing, but more modestly in relation to male authorship.

5. Conclusion

From the data organized in this work it is possible to verify how the female presence in the authorship of theses and dissertations related to Astronomy Education in Brazil is still small compared to the production of male authorship and considering that in statistical terms the women corresponds to 50 % of population over the past 20 years from government data. With this we can say that this area of research has not been developed equally between men and women, even when Astronomy is related to Education, which is usually an area with greater female presence.

It was found that of the theses and dissertations analyzed only 36.4% (136) are with female authorship. Of these, 42.6% (58) are concentrated in six Universities (USP, UEFS, UFRN, UNESP, UNICSUL and UEL) and considering all productions, just 31.4% (92) have women as adviser or co-adviser.

Considering the data of theses and dissertation authorship, it is important to highlight that affirmative actions by institutions to increase female participation are possible. The structures of graduate programs, forms of admission and permanence must be considered.

When we focus on the career of teaching and the area of education, there can be a historical tendency for female participation to be greater through the feminization process of teaching, which assumed a missionary character, so that the so-called feminine characteristics were considered the most important, favorable to the role, such as maternal instinct, docility and submission, unprofessionalization the teaching work and relating it to a vocation (Nacarato, Varani, Carvalho, 1998, p. 77). In this work there is no connivance with this perspective, however it is considered a historical and social fact.

In this sense, we can observe that although the area of Education tends to have a greater female presence and distinctively the area of Astronomy to a male predominance, in the merge of both, Astronomy Education, the predominant gender is similar to Astronomy area.

References

- Bailey, J. M.; Prather, E. E.; Slater, T. F. Reflecting on the history of Astronomy Education research to plan for the future. *Advances in Space Research*, v. 34, p. 2136–2144, 2004.
- Bailey, J. M.; Slater, T. F. A review of Astronomy Educations Research. *Astronomy Educations Review*, v. 2, p. 20-45, jan. 2004.
- Bardin, L. *Análise de Conteúdo*. São Paulo: Edições 70, 2011.
- Bretones, Paulo S.; Megid Neto, Jorge. Tendências de Teses e Dissertações sobre Educação em Astronomia no Brasil. *Boletim da Sociedade Astronômica Brasileira*. v. 24, n. 2, p. 35-43, 2005.
- Bretones, P. S.; Megid Neto, J. An analysis of papers on Astronomy Education in proceedings of IAU meetings from 1988 to 2006. *Astronomy Education Review*, v. 10, n. 1, p. 2011.
- Bretones, P. S.; Megid Neto, J.; Canalle, J. B. G. A educação em Astronomia nos trabalhos das reuniões anuais da Sociedade Astronômica Brasileira. *Boletim da Sociedade Astronômica Brasileira*, v. 26, n. 2, p. 55-72, 2006.
- Bretones, P.; Ortelan, G. B. Temas e conteúdos abordados em Teses e dissertações sobre Educação em Astronomia no Brasil. *II Simpósio Nacional de Educação em Astronomia*, v. 2, São Paulo, 2012.
- Bussi, B.; Bretones, P. S. Educação em Astronomia nos trabalhos dos ENPECs de 1997 a 2011. In: *IX Encontro Nacional de Pesquisa em Educação em Ciências*, Águas de Lindóia, 2013.
- Caniato, Rodolpho. *Um projeto Brasileiro para o Ensino de Física*. 586f. Tese (Doutorado) – Universidade Estadual Paulista, Rio Claro, 1973.
- Fernandes, T. C. D.; Nardi, R. Uma Análise dos trabalhos sobre Educação em Astronomia nos Encontros Nacionais de Pesquisa em Educação em Ciências. *IX Encontro Nacional de Pesquisa em Educação em Ciências*. Águas de Lindóia, SP, 2015.
- Fraknoi, A. A Brief History Of publishing papers on Astronomy Education research. *Journal of Astronomy & Earth Sciences Education*, v. 1, n. 1, p. 37-40, 2014.
- Iachel, G.; Nardi, R. Algumas tendências das publicações relacionadas à Astronomia em periódicos brasileiros de ensino de Física nas últimas décadas. *Revista Ensaio*, v. 12, n.02, p. 225-238, Mai – ago. 2010.
- Instituto Brasileiro De Geografia E Estatística – IBGE. *Distribuição percentual da População por Sexo*. Disponível em: <https://educa.ibge.gov.br/jovens/conheca-o-brasil/populacao/18320-quantidade-de-homens-e-mulheres.html>>. Acesso em: Aug. 2019.
- Leite, Cristina. *Formação do professor de Ciências em Astronomia: uma proposta com enfoque na espacialidade*. 274f. Tese (Doutorado) – Universidade de São Paulo, Faculdade de Educação, São Paulo, 2006.
- Lelliott, A.; Rollnick, M. Big ideas: A review of Astronomy education research 1974-2008. *International Journal of Science Education*. Vol.32, n. 13, p. 1771-1799, set.2010.
- Leta, Jacqueline. Mulheres na Ciência Brasileira: desempenho inferior? *Revista Feminismos*, v.2, n.3, p. 139-152, set-sez.2014.
- Marrone Jr, J.; Trevisan, R. H. Um perfil da pesquisa em ensino de Astronomia no Brasil a partir da análise de periódicos de ensino de Ciências, *Caderno Brasileiro de Ensino de Física*, v. 26, n. 3, p. 547-574, dez. 2009. Disponível em: <<https://periodicos.ufsc.br/index.php/fisica/article/view/2175-7941.2009v26n3p547/14082>>. Acesso em: out. 2014

- Megid Neto, Jorge. *Tendências da pesquisa acadêmica sobre o ensino de Ciências no nível fundamental*. 114f. Tese (Doutorado em Educação) – Faculdade de Educação, Unicamp, Campinas/SP, 1999.
- Megid Neto, Jorge; Carvalho, Luiz M. de. *Pesquisas de Estado da Arte: fundamentos, características e percursos metodológicos*. 2018. (book chapter in press).
- Nacarato, Adair M.; Varani, Adriana; Carvalho, Valéria. O cotidiano do trabalho docente: palco, bastidores e trabalho invisível... abrindo as cortinas. In: Geraldi, C.m.g.; Fiorentini, D.; Pereira, E.M.A. (orgs.) *Cartografia do trabalho docente*. Campinas: Mercados das Letras, ALB, 1998. p.73-104.
- Nascimento, Silvania S. do Um curso de gravitação para professores de primeiro grau. 184f. Dissertação (Mestrado) – Univesidade de São Paulo, Faculdade de Educação, São Paulo, 1990.
- Neves, Marcos C. D. *Astronomia de régua e compasso: de Kepler a Ptolomeu*. 242f. Dissertação (Mestrado). Universidade Estadual de Campinas, Campinas, 1986.
- Ortelan, G. B.; Bretones, P. S. Educação em Astronomia nos trabalhos das Reuniões Anuais da SAB entre 2004 e 2010. In: Reunião Anual da Sociedade Astronômica Brasileira, 37, 2012, Águas de Lindóia. *Boletim da Sociedade Astronômica Brasileira*, Águas de Lindóia, 2012. p. 76.
- Salimpour, Saeed ; Fitzgerald, Michael T. A Glass Ceiling in AER?: A preliminary glimpse at the distribution of authors by gender in the iSTAR (istardb.org) database. *Robotic Telescopes, Student Research and Education Proceedings*, Hilo, Hawaii, USA, 2018.
- Shiebinger, Londa. O feminismo mudou a ciência? Bauru, SP: EDUSC, 2001. 384p. Silva, Adriana V. R. Situação da Mulher na Astronomia Brasileira. In: Sociedade Astronômica Brasileira. *Boletim da Sociedade Astronômica Brasileira*. v. 26. p. 15-29, 2007.
- Simon, Paula C. S. G.; Bretones, Paulo S. A presença feminina na autoria de teses e dissertações sobre educação em Astronomia. *Atas do V Simpósio Nacional de Educação em Astronomia*. 2018. Disponível em: <https://sab-astro.org.br/eventos/snea/v-snea/atas/comunicacoes-orais/co30/>.
- Slater, T. F. The first big wave of Astronomy Education Research dissertations and some directions for future research efforts. *Astronomy Education Review*, v.7, n. 1, 2008.
- Vasconcellos, Elza C. C. E; Brisolla, Sandra N. (2009), “Presença Feminina No Estudo e no Trabalho da Ciência na Unicamp”, *Cadernos Pagu*, 32, Jan/Jun, 215-265, hAp://dx.doi.org/10.1590/S0104-83332009000100008.
- Viegas, Sueli M. M. 20 Anos de Astronomia no Brasil: O lado feminino, *Boletim da Sociedade Astronômica Brasileira*, 13, 3, 27–32, 1994.
- Viegas, Sueli M. M. A Astronomia brasileira no feminino In: Matsuura, O. T. (Org.) *História da Astronomia no Brasil – Volume II – MAST/MCTI*, Cepe Editora e Secretaria de Ciência e Tecnologia de Pernambuco | Recife, 2014a
- Viegas, Sueli M. M. Participação da mulher na Astronomia brasileira. 2014. In: *XXXVIII Reunião Anual da Sociedade Astronômica Brasileira*, 32, 2014, Rio de Janeiro. Atas... Rio de Janeiro, 2014b, p. 1.
- Wall, C. A. A review of research related to Astronomy Education, *School Science and Mathematics*, v. 73, p. 653-669, 1973
- Yannoulas, Silvia C.; Vallejos, Adriana L.; Lenarduzzi, Zulma V. Feminismos e academia. *Revista Bras. Est. Pedag.*, Brasília, v. 81, n. 199, p. 425-451, set./dez. 2000.

An Analysis of Peer-Reviewed Papers on Astronomy Education Published From 2007 to 2019 in Japan

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Abstract

We analyzed 105 peer-reviewed papers on astronomy education published in academic journals from 2007 to 2019 in Japan. The papers have been published in various journals. About one third of the papers are related to topics in primary education. The number of papers on training of in-service teachers and museum curators is small. About one third of the papers deal with the lunar phase, which is one of the main topics in elementary school astronomy curriculum. About two thirds of the papers are related to the Solar System bodies. Compared with cases in international journals and meetings, Japanese astronomy education research focuses on issues in elementary school contents, and in terms of concept, research related to Sun-Moon-Earth system is most common and that on Earth is rare.

Keywords

Astronomy education research, paper review, paper statistics, Japan

1. Introduction

Agata, Karino and Matsumoto (2015) pointed out through analyzing Japanese astronomy education papers published in 2000 to 2015 and presentations at the annual meeting of Astronomical Society of Japan in 1995 to 2015 that there were problems on astronomy education papers published in Japan as follows:

- astronomy education research papers have been published in various journals, and
- the papers were not so well circulated among researchers and practitioners.

To enrich the astronomy education research field, surveying the related papers and reviewing the papers periodically is necessary. The situation is similar in many other countries. Reviews of international papers has been presented by Lelliott and Rollnic (2010), Bretones and Neto (2011), Bretones, Jafelice and Horvath (2016) and many others. Following these papers, we analyzed 105 peer-reviewed papers on astronomy education published in academic journals from 2007 to 2019 in Japan.

2. Material and Method

Japanese Society for Education and Popularization of Astronomy (JSEPA) hosts the working group on astronomy education paper archive chaired by one of the authors of this paper (SK). Since 2017, the working group has collected the peer-reviewed papers in Japan. We have continued to search the electric publication on the internet and the paper-based publication and collected in total 105 peerreviewed papers on astronomy education published in ten academic journals from 2007 to 2019 in Japan. Though we made efforts as much as possible so far to collect all the peer-reviewed papers, there were still some papers left from the list. All the articles are written in Japanese. Though not all of them, some of them attach English titles and abstracts. However, the articles are not well on the international circulation nor included in the international database. The paper list will be open on the JSEPA web site (<http://www.tenkyo.net/>).

3. Results

Table 1 shows number of the papers sorted by journal and year. Statistics in 2019 is that up to September. On average, 8.5 peer-review papers have been published in Japan during the decade.

Table 1: Number of papers sorted by journal and year.

| Year | Journal | | | | | | Total |
|--------------|-----------------|-----------------|-----------------|------------------|-----------------------|-----------|------------|
| | Earth Sci Edu | R Sci Edu | Sci Edu | Edu Tech | Astro Edu | Others | |
| 2007 | 5 (20) | 1 (30) | 4 (55) | 0 (102) | <114> | – | 10 |
| 2008 | 2 (18) | 2 (39) | 0 (42) | 0 (93) | <86> | – | 4 |
| 2009 | 4 (16) | 2 (35) | 2 (34) | 0 (96) | 1 <138> | 2 | 12 |
| 2010 | 3 (10) | 3 (46) | 1 (35) | 1 (88) | <134> | – | 8 |
| 2011 | 2 (12) | 1 (53) | 1 (32) | 1 (88) | <110> | 2 | 17 |
| 2012 | 4 (13) | 1 (53) | 0 (34) | 4 (95) | <155> | 2 | 11 |
| 2013 | 3 (11) | 1 (33) | 2 (31) | 0 (94) | <134> | 1 | 7 |
| 2014 | 4 (12) | 0 (43) | 1 (25) | 0 (74) | 1 <131> | 1 | 7 |
| 2015 | 2 (11) | 3 (35) | 1 (35) | 0 (60) | 1 <99> | 1 | 8 |
| 2016 | 2 (13) | 3 (22) | 0 (34) | 0 (88) | 2 <125> | – | 7 |
| 2017 | 2 (13) | 2 (30) | 3 (48) | 2 (100) | 1 <134> | – | 10 |
| 2018 | 1 (7) | 3 (42) | 2 (39) | 2 (78) | 2 <122> | 1 | 11 |
| 2019 | 0 (5) | 3 (34) | 0 (19) | 0 (7) | <47> | – | 3 |
| Total | 34 (161) | 26 (445) | 17 (463) | 10 (1063) | 8 <1529> | 10 | 105 |

Journal name abbreviation and notes:

- Earth Sci Edu: Education of Earth Science: <https://www.jstage.jst.go.jp/browse/chigakukyoiku/>
Issued by Japan Society of Earth Science Education: <http://www.age.ac/~chigakuk/>
Numbers in parentheses are total number of papers published in the journal regardless of field.
- R Sci Edu: Journal of Research in Science Education: <https://www.jstage.jst.go.jp/browse/sjst/>
Issued by Society of Japan Science Teaching: <http://www.sjst.jp/>

Numbers in parentheses are total number of papers published in the journal regardless of field.

- Sci Edu: Journal of Science Education in Japan: <https://www.jstage.jst.go.jp/browse/jssej/>
Issued by Japan Society for Science Education: <http://www.jsse.jp/>
Numbers in parentheses are total number of papers published in the journal regardless of field.
- Edu Tech: Japan Journal of Educational Technology: <https://www.jstage.jst.go.jp/browse/jjet/>
Issued by Japan Society for Educational Technology: <http://www.jset.gr.jp/>
Numbers in parentheses are total number of papers published in the journal regardless of field.
- Astro Edu: Astronomy Education: <https://www.tenkyo.net/paper/tenmonkyouiku/>
Issued by Japan Society for Education and Popularization of Astronomy: <https://www.tenkyo.net/> Numbers in brackets are total number of papers published in the journal including articles without peer reviewing, such as reports and notes.
- Others: Journal of Japanese Association for Science Communication, Journal of the Japan Information-Culture Society, Journal of the Physics Education Society of Japan, Physics Education in University, Japanese Psychological Review.

Education of Earth Science (Earth Sci Edu) publishes articles on education in geology, meteorology, oceanology, disaster mitigation, as well as astronomy. Roughly speaking, astronomy contents are about one fourth to one fifth of all the contents of Earth science of school textbooks, so it is reasonable that the fraction of papers on astronomy education is 21 % in the journal. In total, about 5 % of articles in general science education journals, Journal of Research in Science Education (R Sci Edu) and Journal of Science Education in Japan (Sci Edu) are astronomy education ones. Considering that the school science curriculum is divided into four domains, namely, physics, chemistry, biology, and Earth science, the percentage is reasonable. The astronomy education field is rich in technological development, therefore, there are several papers in educational technology journals. The journal of Astronomy Education is mainly devoted to a wide area of education and outreach in astronomy and most of the articles in the journal are not peer-reviewed casual ones. However, the articles are very useful to local astronomy education practitioners including amateur astronomers and enthusiasts.

Table 2 shows number of the papers sorted by target with duplication allowed. Many of the papers targeting to pre-service teacher training are for university students who will be elementary school teachers, therefore, papers related to primary education occupies about one third of the total papers.

In-service teacher training research has not been well published compared to pre-service teacher training research. The number of papers related to curator training is small, either.

As a whole, the main topics in Japanese astronomy education research is lunar phase in primary education and Venus phase and planet motion in lower secondary education. As well as that, some papers deal with stellar and galactic astronomy which are the contents in upper secondary education, including development of teaching materials using real professional data such as FITS images and radio data. Though number of examples is still small, citizen science astronomy is emerging, for example, observing parallax of the Moon by collecting many photos from the public.

Table 2: Number of papers sorted by target with duplication allowed.

| Year | Target (duplication allowed) | | | | | | | | | Total |
|--------------|------------------------------|-----------|-----------|-----------|----------|-----------|----------|----------|-----------|------------|
| | PP | P | LS | US | T | PTT | ITT | CT | O | |
| 2007 | – | 4 | 3 | 3 | – | 1 | – | – | 1 | 12 |
| 2008 | – | 1 | 2 | 1 | – | – | – | – | – | 4 |
| 2009 | – | 4 | 1 | 3 | 1 | 2 | – | 1 | 2 | 14 |
| 2010 | – | 1 | – | 2 | 1 | 2 | 1 | – | 1 | 8 |
| 2011 | 1 | 3 | 1 | 1 | – | – | 1 | – | – | 7 |
| 2012 | – | 2 | 4 | 1 | – | 3 | – | 1 | 1 | 12 |
| 2013 | – | 1 | 3 | 1 | – | 1 | – | – | 1 | 7 |
| 2014 | – | – | 1 | 3 | – | – | 2 | – | 1 | 7 |
| 2015 | – | 1 | 1 | 1 | – | 4 | – | – | 1 | 8 |
| 2016 | – | 2 | 2 | – | 1 | 1 | – | – | 2 | 8 |
| 2017 | – | 4 | 2 | 3 | – | 3 | – | – | 1 | 13 |
| 2018 | – | 2 | 3 | – | 2 | 2 | – | – | 2 | 11 |
| 2019 | – | 2 | – | – | – | – | – | – | 1 | 3 |
| Total | 1 | 27 | 23 | 19 | 5 | 19 | 4 | 2 | 14 | 114 |

Target abbreviation:

PP: pre-primary education,

P: primary education,

LS: lower secondary education,

US: upper secondary education,

T: general tertiary or university education,

PPT: pre-service teacher training,

ITT: in-service teacher training,

CT: curator training,

O: astronomy outreach

Table 3 show number of the papers sorted by contents. Only frequent contents are shown in the table. The most frequent one is phase and motion of the Moon which is one of the main contents in astronomy primary education. This is in line with the result shown in table 2 that the primary education field is dominant in astronomy education research. Phase of Venus is one of the main topics in lower secondary education. Through this topic, students are expected to learn that Venus orbits the Sun, not the Earth, and to understand deeply the reason of the phase, though the topic is not an easy one for both students and teachers. As a whole, about a half of the papers are related to lunar and Venus phases.

Table 3: Number of papers sorted by contents.

| Year | Contents (frequent ones only) | | | | | | | | | Total |
|--------------|-------------------------------|--------------|----------|----------|----------|----------|----------|----------|----------|-----------|
| | A | B | C | D | E | F | G | H | I | |
| 2007 | 2 | 2(1) | – | – | 1 | 1 | 1 | – | 2 | 9 |
| 2008 | 1 | – | 1 | – | – | – | – | – | 1 | 3 |
| 2009 | 4 | 2 | 1 | 1 | 2 | – | – | 1 | 1 | 10 |
| 2010 | 4 | – | 1 | 1 | – | – | – | 1 | – | 7 |
| 2011 | 2 | – | 1 | 1 | – | – | – | 1 | – | 7 |
| 2012 | 5 | 2 | – | 1 | – | 1 | – | – | – | 9 |
| 2013 | 1 | 2(1) | 1 | – | – | 1 | – | – | – | 5 |
| 2014 | – | 3(1) | 1 | 1 | – | – | – | – | 1 | 6 |
| 2015 | 4 | 1 | – | – | – | – | – | 3 | – | 8 |
| 2016 | 3 | 2(1) | – | 1 | 1 | – | – | – | – | 7 |
| 2017 | 5 | – | – | – | – | – | 1 | 2 | – | 8 |
| 2018 | 3 | 2(2) | – | 2 | – | 2 | 1 | – | – | 10 |
| 2019 | – | – | – | 1 | – | – | 1 | – | – | 2 |
| Total | 34 | 16(6) | 6 | 9 | 4 | 5 | 4 | 8 | 5 | 91 |

Contents:

- A: phase and motion of the Moon,
- B: Solar System, including phase and motion of the planets, determination of orbits of planets including the Earth; numbers in parentheses are ones related to Venus phase,
- C: making and handling telescope,
- D: celestial sphere, cardinal direction, motion of the Sun and stars on the celestial sphere,
- E: light emission and radiation,
- F: solar and lunar eclipses,
- G: sundial, light and shadow,
- H: stellar astronomy including molecular clouds or black holes,
- I: galactic and extragalactic astronomy, cosmology.

4. Discussion

Lelliott and Rollnic (2010) examined 103 articles in leading international science education journals appeared in from 1974 to 2008. In table 3 of the paper, articles were sorted according to the big ideas, such as Earth-Sun-Moon system, Solar System, Seasons, and so on. With duplication allowed, about one third of the papers are related to Earth-Sun-Moon system and another about one third is related to Day and Night. This is similar to the Japanese case shown in section 3. The most frequent topic in the paper is Earth conception. On the other hand, there are few papers on Earth conception in Japan. Bretones, Jafelice and Horvath (2016) analyzed 75 articles published in 18 editions in ten years of Latin-American Journal of Astronomy Education, RELEA. In table 5 of the paper, articles were sorted according to the topics of contents. Apart from the content of general of 33.3 %, the most frequent content is Sun-Earth-Moon system of 26.7 % and the next one is Solar System of 18.7 %. This is similar to the Japanese case. As a whole, topics related to Earth-Sun-Moon system are common ones regardless of countries.

In table 3 of Bretones, Jafelice and Horvath (2016), the articles were sorted by school grade level. From university, high school, middle school to elementary school, fraction is decreasing as 28.0 %, 28.0 %, 8.0 % and 1.3 %. This is opposite to the Japanese case where the research focuses more on elementary school. Bretones and Neto (2011) analyzed 283 papers on Astronomy Education in Proceedings of IAU Meetings from 1988 to 2006. In table 3 of the paper, the articles were sorted by school grade level. Again, the trend is similar to that in Bretones, Jafelice and Horvath (2016), that from university, high school, middle school to elementary school, the fraction is decreasing as 37.8 %, 12.0 %, 10.0 % and 7.8 %.

5. Conclusions

We analyzed 105 peer-reviewed papers on astronomy education published in academic journals from 2007 to 2019 in Japan. The papers have been published in various journals. Japanese astronomy education research papers focus more on lower-grade schools which is opposite to the international case. On the other hand, the contents in Japan are similar to the international one that Earth-Sun-Moon system is the most focused topic. In Japan, lunar and Venus phase is the central issue for teachers to develop teaching materials and methods.

There are many high-quality astronomy education research papers written in Japanese, however, these are not so well in the international circulation due to the language barrier. It is not realistic for Japanese educators and practitioners to write papers in English. Introducing annual review of Japanese achievement in English which would appear in new astronomy education journal can bridge this gap.

References

- Agata, H., Karino, S., and Matsumoto, N (2015) “Astronomy Educations as a Branch of Academic Discipline” *The Astronomical Herald*, 108 (8), 521-528.
- Bretones, P.S., Jafelice, L.C., Horvath, J.E. (2016) “Ten Years of Latin-American Journal of Astronomy Education RELEA: Achievements and Challenges for International Astronomy Education Development” *Journal of Astronomy & Earth Sciences Education*, 3 (2), 111-124.
- Bretones, P.S., and Neto, J.M. (2011) “An Analysis of Papers on Astronomy Education in Proceedings of IAU Meetings from 1988 to 2006” *Astronomy Education Review*, 10, 10.3847/AER2010010.
- Lelliott, A., and Rollnick, M. (2010) “Big Ideas: A review of astronomy education research 1974-2008” *International Journal of Science Education*, 32 (13), 1771-1799.

Session I.II

Astronomy Education Standards, Curriculum and Instruction

Teaching stellar astrophysics in the middle/high school

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Abstract

We discuss in this work the construction and application of a teaching/learning sequence to introduce stellar astrophysics in the Middle/High school. This topic is treated as an ideal interface for many physics which run separately in the curricula. We have found that a straightforward, “astronomical mood”, approach indeed produces a good deal of interest and excitement, contextualizes the physics learned by students, but does not hold as cognitively significant after one year, time interval in which the evaluation is repeated. This suggests that effective educational actions should be not only carefully planned, but also revisited in time to hold, a subject which is not always recognized and emphasized, but present in the “spiral” design of school curricula.

2. Introduction

The issue of school curricula is quite central to the education quest in any society, independently of its specificities. As a general trend, Western schools have adopted, following the specialization trend of the sciences, a compartmentalization of school disciplines deemed inevitable for the teaching task. This has, on the other hand, quite harmful consequences for the construction and perception of sciences as a whole, because students seldom have a synthetic capability required to relate several topics into a unified corpus. The unity and coherence of sciences as an endeavor of mankind under a rationalist perspective, albeit using a variety of tools and methods, is not easily grasped and incorporated.

A cursory look of any Western Middle/High school including the discipline “Physics” will reveal some ubiquitous topics such as calorimetry, elementary optics, particle motion, electrostatics and the like [1]. These subjects have been defined and introduced mainly in the late 19th century, and in spite that they are very relevant today, drive the students to separate the subjects quite sharply, with the consequent partial view which is never integrated as it should. Many attempts to update and address the 20th century topics (radiation, quantum phenomena etc.) have been performed, but with limited success according to our view (see [1] for the newest attempt in USA, and [2] for an Australian version). Turning to our main interest, astronomy, it has been present as a subfield in physics/mathematics classes in many cases with increasing strength. However, it is mainly the “old” astronomy which is addressed, mainly up to the 17th century, including Kepler, Copernicus, Galileo and fellows, as well as the topics that stress Astronomy as a natural science presented in the Elementary school: Moon phases, eclipses and related subjects [3]. We do not want to underestimate the benefits of a good education including the natural astronomy, but it is quite clear that the state-of-the-art of astronomy goes well beyond this. In fact, it is the *frontier* topics in astrophysics and cosmology that are overwhelmingly present in the modern society and fascinate the students [4]. The curiosity about black holes, the expansion of the Universe and many other things contrast with the conservative offering of “classical” topics, and the contemporary school does not give a satisfactory answer to these knowledge demands. In fact a very interesting discussion on the adequacy of introducing modern astrophysics in the Middle/High school has been started by Pasachoff [4] arguing vigorously for the persistence of the efforts devoted to teaching of modern subjects, while many educators argued that such a thing is hopeless and that “less is more” [3,5]. What we rise here is the idea and example of stellar astrophysics as an integrating topic and a valuable and inspiring topic by itself. We will relate below one teaching experience addressing how we devised a teaching-learning sequence, how it was applied and what the results reveal and suggest for further work.

3. Stellar astrophysics: a meeting point and its difficulties

We have already pointed out the “natural” character of the astronomy addressed in school curricula. This character is precisely the motive of a slightly deeper thought to be considered when addressing other astronomical subject(s). As long as human senses suffice to apprehend the astronomical reality, there is an advantage of natural astronomy over the objects falling into the realm of a more abstract conception of science. In this sense, it is clear that stars mark the *borderline* between this “natural” astronomy and the field of modern astronomical knowledge. We contend that stars and stellar structure/evolution are epistemologically different from the “old”, classical astronomical knowledge: human senses do not help much, and actually the present knowledge of stars is a combination of powerful technological tools developed along the last century or so, and the arena in which all modern physics function together to

construct a consistent picture of the subject. In other words, it is not difficult to see that the strong advance of physics in the last century allowed stellar structure and evolution to achieve its present status. Stellar astrophysics is the legitimate heritage of all the revolutionary developments and at the same time the consolidation and extension of pre-existing “classical” physics.

It is illuminating to see these facts in the light of the thought of Galileo, who desired astronomy to be discussed by common people (not only by scholars) in the 16th century [6]. This very generous and idealistic thought is somewhat the reverse tendency of what happens nowadays: astronomy became a very hermetic discipline to be grasped, using sophisticated instruments far from the common usage, and concepts which are quite involved and elaborated, sometimes an oddity to the common sense. The layman has then to deposit a high degree of confidence on astronomers, because most of the time their studies cannot be easily transmitted and understood, although they remain fascinating. This is why astronomy education is even more necessary than ever, because the curiosity and interest of the people requires high efforts to overcome the hermetic nature of the science. We believe this point underlies all the Pasachoff/USA educators controversy [3,4,5], which is not settled by any means. We claim therefore an *epistemological barrier*, more or less when the stars as cosmic structures and common objects are considered. While they are and ideal melting pot of modern/classical science concepts and methods, they cannot be investigated directly (with the exception of some properties of the Sun) without instruments and advanced scientific knowledge. The empirical approach attempted within the nearby Solar System objects will break inevitably when considering stars, even at some basic level.

3. Setup and details of the educational proposal

To test how to deal with these topics we formulated a proposal to teach stellar astrophysics as a melting pot of 20th century “modern” physics, reinforcing the symbiosis of physics and astronomy and stressing the unity of sciences. For that purpose we devised a didactical sequence of four lessons containing the basic material. We applied this sequence at the state public school “E.E. Prof. Gabriel Ortiz” located in São Paulo city to two groups of students 14-15 years old, a total of 69 individuals. They had been exposed to basic mechanics, electromagnetic phenomena, calorimetry and related subjects prior to the astronomy lessons. The whole plan and rationale for each of the lessons are shown in Fig. 1. The lessons were expository and made use of a semi-quantitative language, patterned after the student’s experience with all other disciplines, enriched with astronomical images, diagrams and short videos. We note the recent publication of a work by the Italian group [7] within a similar approach and containing very relevant qualitative analysis of the student’s difficulties.

As a benchmark for the later test of the results of this experiment a questionnaire was applied to the students containing a basic appraisal of their knowledge and thoughts on stars (Fig. 2). We collected the answers and organized them according to bins defined by the actual data, not by any *a priori* scheme. We have applied the questionnaire with categories of contents about stars. With the answers, we have used a simple List, Category, Ranking, Quantity, Grid and Scale as described in [8]. The issues span practically all the pretended goals listed in Fig. 1, although with different “weights” and emphasis. The lessons were given to them, and several comments and observations collected as appropriate for a qualitative analysis (see below). Generally speaking, the cognitive gain was quite substantial after the completion, although we were not particularly interested to quantify it, because our goal was to understand whether this feature was *persistent in time* or rather ephemeral, vanishing in time without long-term effects.

Table 1: The plan of four lessons containing basic notions and pretended goals for each one (Bandecci, Ref.[9])

| Class | Subject | Conceptual goals |
|-------|-----------------------------|--|
| 1 | — <i>Starrysky</i> | — Understanding what galaxies are and their characteristics |
| | — Constellations | — Understand the historical & cultural context of the constellations |
| | — Magnitude | — Assimilate the concepts of magnitude and flux and their relationship to color & temperature |
| | — Flux | |
| | — Color & temperature | |
| | — Radiation | — Understanding what is radiation and its relation to stars and Astronomy |
| 2 | — HR Diagram | — Understand the HR Diagram and the relation to Stellar evolution |
| | — Molecular clouds | — Understand the formation of stars and the beginning of their evolutionary cycle |
| | — Virial Theorem | |
| | — Gravity & Pressure | — Understand the relation between gravity & pressure and how these factors interfere with Stellar Evolution |
| 3 | — Nuclear fusion | — Understand the formation of chemical elements through nuclear fusion and how it results in energy production |
| | — Energy production | — Understand what Hydrostatic Equilibrium is and how important it is for the evolution of stars |
| | — Hydrostatic equilibrium | |
| | — Red Giant | — Understand the final stage of Stellar Evolution and the Red Giant concept |
| 4 | — Planetary nebula | — Understand what is a planetary nebula |
| | — White dwarf | — Understand the concept of White Dwarf |
| | — Supernova | — Understand the end of very massive and a not massive stars |
| | — Black hole/Neutrons stars | — Understand the Supernova Explosion concept — Understand and differentiate a black hole and a neutron star |

Table 2: The questionnaire applied to the sample of 69 students of the public school at São Paulo.

| Final Questionnaire | |
|----------------------------|--|
| 1 | Draw an actual star |
| 2 | Put a name on it |
| 3 | What is this star made of? |
| 4 | What is its temperature? |
| 5 | Which color is it? |
| 6 | How old is it? |
| 7 | Which is the size of the star (compared to the Earth)? |
| 8 | What is the energy source of the star? |
| 9 | You can observe the star for several years without noticing any changes. How do you think the star stays this way? |
| 10 | What is light and how important is it to the stars? |
| 11 | Is the star going to stay like that forever? What will happen afterwards? |
| 12 | Which is the rule of gravity in the formation and evolution of stars? |
| 13 | What is the relation between stars and chemical elements? |

The same questionnaire was applied at the school after a full year, and the results compared question by question. Only 11 of the original 69 students were still present, but their original and new answers were compared collectively and individually. The answers to some relevant questions are compared in Figs. 3, 4 and 5.

It is quite clear that after 1 year the results show a *regression* of the student's knowledge to the pre-lesson state or worse. At face value the "acceptable" answers receded from 50% to 28%, 86% to 18% and 40% to 18% respectively. Even acknowledging the small sample size, and therefore the large fluctuations that might be present, the results are qualitatively discouraging. To check whether this particular result was due to a selection effect of the worst students remaining in the sample (unlikely, but possible), we proceeded to compare their answers one-by-one after the lessons and 1 year later (Fig.6).

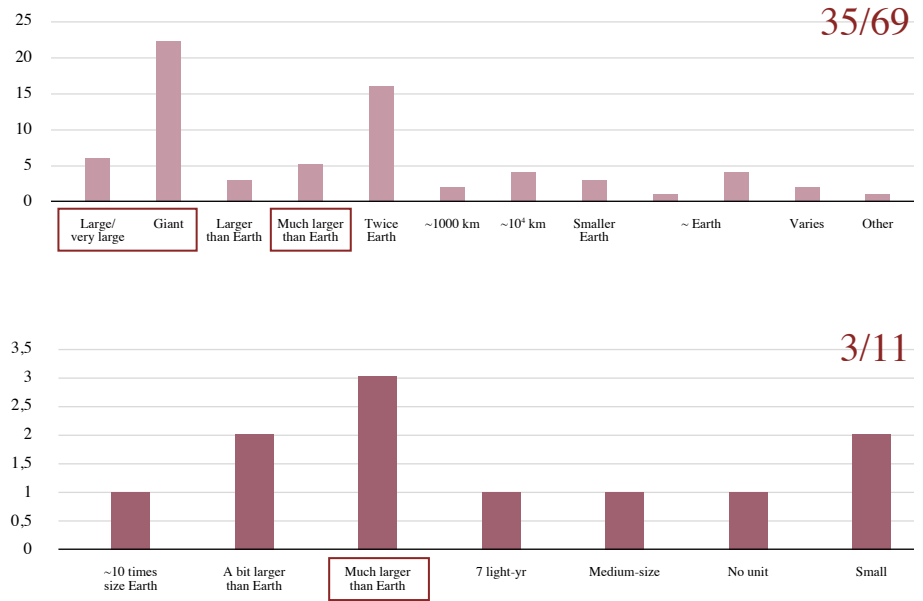


Fig. 3. Comparison of the answers about the size of a star (Q7 in Fig. 2). Above: original answers (69 students). Below: answers after 1 year of the remaining 11 students. The red rectangles point out the answer(s) that were considered “acceptable”. The red numbers in the upper corner reflect the number of acceptable answers of the total sample in each case.

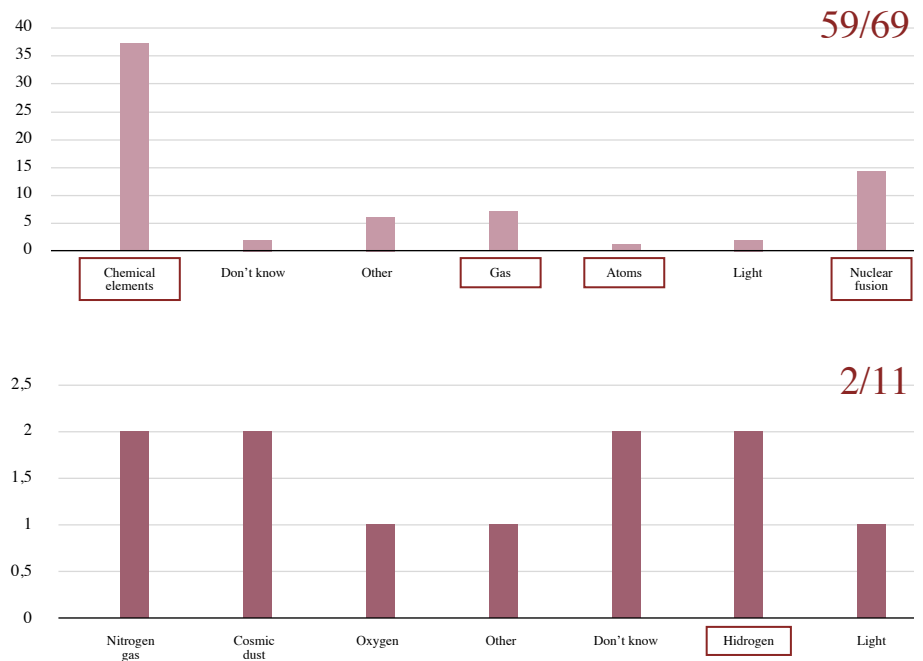


Fig. 4. Same as Fig. 3 for the Q8 in Fig. 2 (note that after 1 year this question was phrased more precisely). Above: original answers (69 students). Below: answers after 1 year of the remaining 11 students. The red rectangles point out the answer(s) that were considered “acceptable”. The red numbers in the upper corner reflect the number of acceptable answers of the total sample in each case.

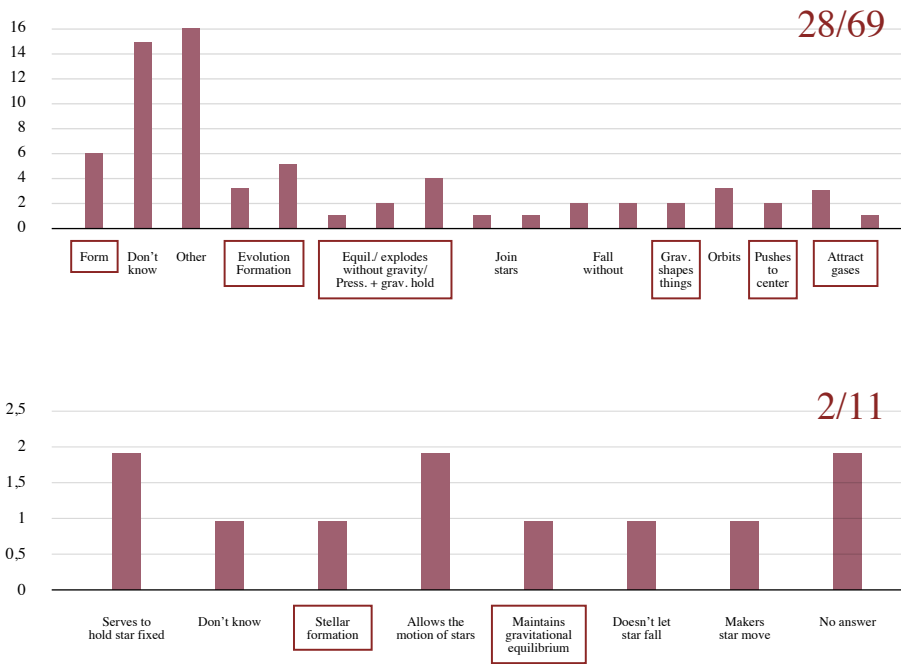


Fig. 5. Same as Fig. 3 for the Q12 in Fig. 2. Above: original answers (69 students). Below: answers after 1 year of the remaining 11 students. The red rectangles point out the answer(s) that were considered “acceptable”. The red numbers in the upper corner reflect the number of acceptable answers of the total sample in each case.

Table 6: The comparison of individual students present in the original sample with their answers after 1 calendar year.

| Student | ✓ | Final vs 1-yr | × |
|---------|----|---------------|----|
| S1 | 5 | | 8 |
| S2 | 8 | | 5 |
| S3 | 11 | | 2 |
| S4 | 2 | | 11 |
| S5 | 8 | | 5 |
| S6 | 5 | | 8 |
| S7 | 11 | | 2 |
| S8 | 5 | | 8 |

| | | |
|-----|---|---|
| S9 | 5 | 8 |
| S10 | 6 | 7 |
| S11 | 7 | 6 |

- ✓ Right answer after a whole year
- ✗ Wrong answer after a year, in many cases going from previously right answers

The number of “acceptable” answers of this group is marked with a “check”. In the last column, the number of “unacceptable” answers, marked with an “X”. In many cases performed worse than their own answers in the previous questionnaire. This suggests a true regression in their concept and knowledge of stars features and basic mechanisms.

As a part of the evaluation, although not yet fully completed, we should mention the application of the same questionnaire to a sample of São Paulo U. (USP) students following geography, arts, history and related careers. The students were taking a general astronomy course roughly equivalent to Astronomy 101 in USA. Not enough time elapsed to repeat the “1-yr after” test, but some results reveal another interesting feature: the resilience of concepts, that is, the small improvement before and after the lessons discussing stars (Fig. 7). It seems that, in spite of the attempts of bringing them closer to the present astronomical view, young adults have difficulties in grasping new facts, at least in the conventional way astronomy is presented. This hypothesis should be further tested and the persistence of knowledge in time evaluated later on.

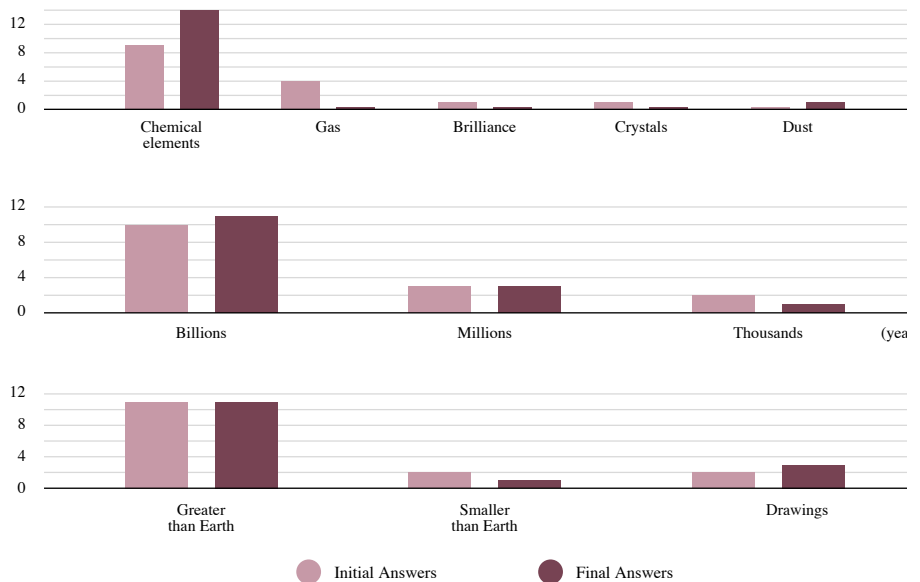


Fig. 7. Initial (light maroon, pre-lessons) and final (dark maroon, post-lessons) answers of USP humanities students to Qs 3 (above), 6 (middle) and 7 (below) of the questionnaire shown in Fig.2. The composition became clearer, but not the age or size for most of the university students.

4. Conclusions

We have described the outcome of a pedagogical experiment with Middle/High school students of a public school in São Paulo and an initial study with humanities students at the USP basic astronomy course. Our conclusions are qualitative and tentative by now, but we believe to have shown that a simple, traditional lesson-based approach does not guarantee an actual apprehension of knowledge in science in a long run, at least for the case of Stellar Astrophysics taken as an example of syncretic discipline intended to integrate several branches of physics, mathematics and related topics. In other words, the “hard science” way of teaching, patterned after the practitioners of astronomy without much attention to the students themselves may have a low impact indeed, vanishing after a period of time.

It is tempting to link this results to the findings in neuroscience, a fundamental line of thought to make some progress towards a better effectiveness of the teaching/learning process in such attempts. The work of many people, notably represented by E. Kandel, suggests that a cognitive process is consolidated into the brain in a short time-scale, but its stabilization lasts much longer (Fig. 8) [10]. Moreover, the human brain shuffles the information and makes new connections each time that the issue is brought back, resulting in a different “storage” linking the latter to a myriad of concepts, sensations and other information. In the long run the useful and acceptable fixation of information such as stars will not stabilize properly if it is not revisited. This suggests a) a careful design of the teaching/learning sequences (because straightforward ones will not be effective, as demonstrated here), and also a strategy to revisit these subjects from time to time, to induce the aimed stabilization. This is a long-standing problem in education, and has been discussed extensively (see, for instance, Ref. [11]. A point of view from Disciplinary Discernment has been presented in [12]. Generally speaking, it is NOT enough to proceed in the “astronomical mood”: offering /presenting the material in a standard form does NOT automatically guarantee a cognitive/conceptual gain in the long run. How to do this and many other questions remain a fertile field of education research.

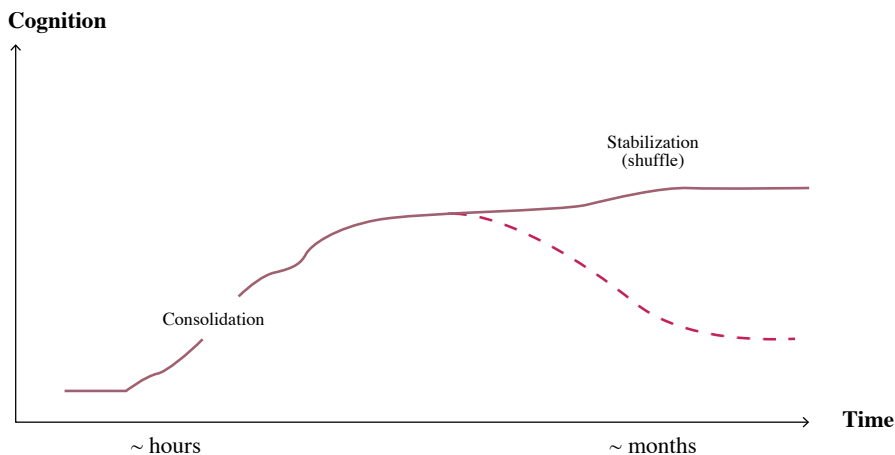


Fig. 8. A rough scheme of the cognitive stabilization in the human brain. The absence of a revisit of an issue may turn the desired trend (maroon) into a degrading path (short dashed pink line) after some months. This phenomenon is very likely the one observed in our experience.

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References

- [1] USA Next Generation Science Standards. <https://www.nextgenscience.org/dci-arrangement/hs-ess1-earths-place-universe> (accessed Set 2020).
- [2] Australian Curriculum. <https://www.australiancurriculum.edu.au/senior-secondary-curriculum/science/earth-and-environmental-science/?unit=Unit+1> (accessed Set 2020)
- [3] Lindell Adrian, R., & Bao, L. 2001, *Students' Initial Model State of Lunar Phases*, contributed talk, AAPT/AAS 2001 Winter meeting, San Diego, California.
- [4] Pasachoff, J. 2002, *What Should College Students Learn? Phases and Seasons? Is Less More or Is Less Less?*, *Astronomy Education Review*, 1(1), 124, and references therein.
- [5] Sadler, P., 2001, *Choosing Between Teaching Helioseismology and Phases of the Moon*, *The Physics Teacher* 39, 554–555.
- [6] Stanford Encyclopedia of Philosophy. <https://plato.stanford.edu/entries/galileo/> (accessed Set 2020)
- [7] Colantonio, A., Galano, S., Leccia, S., Puddu, E., Testa, I. 2018. *Design and Development of a Learning Progression about Stellar Structure and Evolution*, *Physical Review Physics Education Research*, 14, 010143.
- [8] Bell, J., 2010, *Doing your research project: a guide for first-time researchers in education, health and social science*, 5th edition Open University Press, London.
- [9] Bandecchi, M. 2018, *Master Education Degree* (in portuguese), available at https://www.iag.usp.br/pos/sites/default/files/d_monica_b_f_vieira_corrigida.pdf
- [10] Kandel, E., Schwartz, J.H, Jessell, T.M., Siegelbaum, S.A., Hudspeth, A.J. 2012, *Principles of Neural Science*, Mc Graw-Hill, NY
- [11] Bruner, J. S. (1977). *The process of education* (2nd ed.). Harvard University Press, USA
- [12] Eriksson, U., Linder, C., Airey, J., Redfors, A. 2014. *Introducing the anatomy of disciplinary discernment: an example from astronomy*, *European Journal of Sciences and Mathematics Education* 2, 167-182

Blue and the Sky: An astronomy education project for pre- (and primary) school children

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Abstract

In this paper we report the design and implementation of an educational project, based on a collaborative and metacognitive learning approach. The project was aimed at very young children and designed around the leading character of a blue sphere called Blue. The creation of the character of Blue stems from the need to find an effective interlocutor in astronomical education for kindergarten (and primary school) sector: Blue is not a dispenser of knowledge, Blue knows nothing about our Planet, Blue doesn't even know what Blue is. Children tell Blue about our world and the Universe, with their simple words. Who reads and listens Blue's adventures could explain many things, maybe obvious and trivial for us but not for Blue. What are days and night? What is a star? And what is the light? Each child discover himself/herself as the bearer of knowledge and experiences and becomes aware of being part of a Universe full of lot of things to be explored. In this article we present the general outline of the educational project and its application during the 2018/19 school year in two kindergarten schools of the Cagliari hinterland. We also present some in progress evolutions of the project.

1. Introduction: science at kindergarten age

“The native and integral attitude of childhood, marked by ardent curiosity, by fertile imagination, and by the love of experimental research, is close, very close, to the attitude of the scientific spirit.”

(Dewey 1910)

Doing science with very small children, especially in the kindergarten ages, is something that should seem difficult. Are young children able to properly understand basic physical principles? Of course, the answer is yes. Children, especially if very small, have a natural, unconscious, “scientific” attitude. In a very natural way, they want to know the “what”, the “how” and the “why” of the world around them, exactly the same questions at the basis of the scientific knowledge. Moreover, it is well demonstrated that even small children are able to problematize objects, events and situations in the physical world, mentally elaborating components of the physical and social environment, developing organized and analytical thinking as well as problem-solving skills and producing cognitive tools through which they are able to “reconstruct” reality.

On the other hand, many activities, which normally take place in the classroom with children, have strong scientific components and characteristics: scientific education in kindergarten is mainly based on careful observation of events through sensory experience, and on the use of oral, iconic, musical and kinesthetic languages. So teachers could use normal daily activities to introduce science contents, it is only a matter of grasping them, exploiting them and developing them. The development of knowledge and the typical ways of proceeding of science, driving children to the practice of intellectual (such as comparison, observations, classifications, experimentation, quantification) and logic operations (such as equivalence and identity, correspondences, analogies, differences), allow them to discover that they can go beyond what they could perceive with the senses.

Finally, beginning inquiry-based science instruction in the early school grades is sometimes suggested as a way to prevent the negative patterns whereby children tend to view science as more difficult and less enjoyable to learn than other subjects are (Andre et al., 1999).

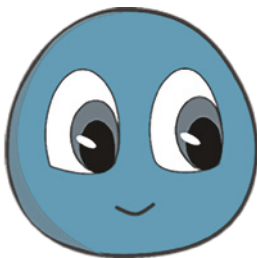


Fig. 1: The character of Blue
(© INAF-OAC)

2. The educational project “Blue and the sky”: General description.

In this article, we will summarize the general lines of a pilot educational project carried out by the Cagliari Astronomical Observatory, one of the structures of the Italian National Institute for Astrophysics (INAF), during the school year 2018-2019.

INAF has a long experience in the design and production of educational projects and material for students of any age and academic level, both locally and nationally (see for example the experience of the Italian portal Astro.edu). One of these projects has been recently developed around a guide character, a blue sphere called Blue (in Fig. 1).

The creation of the character of Blue stems from the need to find an effective new interlocutor in astronomical education for the childhood (and primary school) sector. The use of guide characters to convey contents in astronomy education and outreach is quite common: they can be kid or teens like, for example, Talma, the character used in the ALMA Kids cartoon series “The adventures of Talma”¹⁰, or the INAF character Martina Tremenda (Marty Naughty)¹¹, curious girl protagonist of hands-on laboratories¹², a book¹³ and a theatre show¹⁴, both targeted to 8-13 years kids. Or they can be little alien, like Paxi¹⁵, famous character of ESA Kids program, targeted to children

10 <http://kids.alma.cl/follow-almas-discoveries-along-with-talma/>

11 <https://edu.inaf.it/index.php/tag/martina-tremenda/>

12 <http://astrokids.inaf.it/>

13 <https://edu.inaf.it/index.php/astrokids-avventure-e-scoperte-nello-spazio/>

14 <http://astrokids.inaf.it/lo-spettacolo/>

15 https://www.esa.int/kids/en/about_Paxi/Paxi

aged from 6 to 10 years, not only the main character of a famous cartoon-style movie series, but even a real space mascot, present even on board of the ISS.

INAF Blue character is a blue sphere, with no apparent gender, coming from a very distant and extremely small (and bare) rocky planet. Being bored of this small planet, Blue decides to leave it and, traveling through the Galaxy, discover the existing great variety of cosmic objects. At a certain point, Blue sees a little pale blue dot and decides to get closer, being captured by its gravity. Once landed to Earth, Blue meets two children and they quickly become friends.

The story-telling contest is an essential part of the project: the (astronomer) tutor tells the story of Blue until the arrival on Earth, creating an emotional relationship with the children. The fact that Blue is “real” (in the form of a puppet, see Fig. 2) facilitates the process of empathy and identification with children.

Unlike Paxi (used by ESA to explain astronomy to children), Blue does not know our planet (and is completely unaware of what is a planet!). Blue is not a dispenser of knowledge, Blue is not able to explain anything because Blue does not know anything. But Blue is curious and creative, wants to learn and makes a lot of questions (especially a lot of “Why?”).



Fig. 2: Blue puppet

2.1 Adopted methodology and educational approach.

The general teaching strategy of this pilot educational project has been developed in agreement with the involved teachers. In particular, we adopted a collaborative learning approach, considered as one of the important applications of social constructivist learning approach (Piaget, 1957; Terhart, 2003).

The learning process adopted is:

- **LUDIC:** children joke and play with Blue. Learning by playing, children can develop social and cognitive skills, mature emotionally, and gain the self-confidence required to engage in new experiences.
- **ACTIVE and LEARNER-CENTRED:** children guided the learning experience trying to explain astronomy and physics processes and phenomena to Blue and they do self-chosen hands-on activities. Active learning naturally coordinates with the principles of constructivism, which are cognitive, meta-cognitive, evolving and affective in nature (Piaget, 1957). In this approach, teachers have a role as facilitators rather than being instructors. Children were constantly engaged – by tutor and teachers – to help Blue to learn and understand the world around them and actively or experientially involved in the learning process (Bowen & Eison, 1991). Trying to explain to Blue their own world, children discover themselves, in a very natural way, as the bearer of knowledge and experiences and becomes aware of being part of a Universe full of new things to explore. In this way, the students can develop themselves both socially and individually (Slavin, 1990). In the same time, children are invited to use their preferred tools to investigate and explain (words, examples, experiments, draws, ...).
- **COLLABORATIVE:** Teachers and tutor facilitate the processes, but children must find – TOGETHER – a way to explain to Blue the phenomena of the world around them, with simple words and concrete examples. Ample space was devoted to free discussion between peers. Cooperative approach is effective in supporting the multiple intelligences theory on student performance (Gardner, 1983).

Recent studies demonstrated that cooperative learning method effectiveness is increased if the interaction among the students groups is constructed through metaco-



Fig. 3: Children tell a tale to Blue using black cardboard shapes.



Fig. 4: What is the meaning of opaque? Children explore the properties of radiation-matter interaction.



Fig. 5: Let's play with light!

gnitive skills (Jbeili, 2012). Metacognition is a complicate and difficult term, but we could assume it as the self-awareness of students in the cognitive processes such as planning the solution of a problem.

2.2 The project execution.

The project was carried out in two childhood institutes in the Cagliari hinterland (Maracalagonis/Burcei e San Basilio/Senorbi/Barrali). It involved **164 students (81 girls and 83 boys)**, aged from 4 to 5 years, plus a small number of 6 years old children (20), divided in class groups (16 – 22 children in each group). Moreover, **18 teachers** in total were involved in the project activities.

The project started in November 2018 with some preliminary meetings with involved teachers in order to define topics to be covered and to define and share methods and strategies. In January 2019, we started the in-class modules. We carried out four modules per group, designed on the following topics: light properties; shadows; colors of light; movements of Earth / Sun / Moon; day and night; stars and constellations.

Each module was designed with a short introduction (Blues sees something and starts to make questions) followed by choral discussion – moderated by tutor – and some simple hands-on activities and experiments. Children drove most of the activities: for example, exploring different ways to explain light properties to Blue, some groups decided to create some cardboard shapes to tell a tale (Fig. 3).

During the representation, all the children naturally discover the physical properties of shadows. In particular, they discovered the different response to the light passage of various materials (opaque, transparent, translucent. See Fig. 4).

All the activities provided lot of space for the playing phase (see Fig. 5).

The week after the meetings with the tutor, teachers consolidated in the classroom the experiences, verbalizes, assesses satisfaction and the relational climate established between peers and not.

The project ended at the beginning of June 2019 with a visit at the Cagliari Observatory headquarters (and the vision of a Planetarium show specially created as a video message from Blue travelling in space) and a final global event carried out at the Sardinia Radio Telescope site.

2.3 The project final event.

A particular care has been devoted to the project final event. In agreement with teachers, we decided to organise the final event as a sort of a science fair, in which children could decide which topic they were willing to show and explain their parents and relatives and, of course how to do it. Moreover, they were pushed to create some exhibits or design some panels or invent some games

We used the Sardinia Radio Telescope visitor center to host some musical performances (a figurative representation of the popular Italian song “Messer Galileo”¹⁶), while we equipped the external square with three gazebos to host panels and exhibits hand-made by children. Produced exhibits were extremely various: some groups decided to create big cardboard panels with known and invented constellations (see Fig. 6), some reproduced our Sun and some planets with papier-mache (Fig. 7), and some other created astronomy inspired puzzles and solar meridians. One group also organized a kind of quiz for parents based of the letters of the alphabet (Fig. 8) and even some athletic team games, involving also the parents (Fig. 9).

16 <http://www.rai.it/dl/RaiTV/programmi/media/ContentItem-de23737e-2130-424d-bcea-96548ac215d6.html>

2.4 Inclusion and evaluation aspects of the project.

An important part of the project has been devoted to the verbalization of the satisfaction and the assessment of children motivation. In particular, a big effort has been put in the valuation of the children's belief about their competence and skills in "being scientist" and in the discussion about their ability to find an easy way to explain scientific (and astronomical) concepts. How students conceptualize the subjects they learn about is indeed closely related to their beliefs about themselves as learners of that subject. In contrast to the quantitative approach, we hence took to measuring perceived competence and liking, we used open-ended questions and qualitative analysis to identify children's beliefs about what science involves.

With this aim, we put particular attention to the gender-inclusive instructional practices. Even if the interest for science is naturally and equally present in very young boys and girls, we know that they likely will experiment some future differences in liking and competence perceptions about science. One reason could be identified in the perpetuating of masculine stereotypes of science and scientists (Scantlebury & Baker, 2007). Another reason could be that the format and content of science experiences tend to be aligned with boys' instructional preferences, and less so with girls' (Koch, 2007). In fact, many boys enjoy competition and de-contextualized activities, and they tend to dominate discussions and handling of equipment and materials. In contrast, girls have a natural attitude for doing science and making connections with what they learn, preferring instructional formats that involve interaction, discussion, and collaboration (Scantlebury & Baker, 2007). Therefore, we tried to assume gender-inclusive practices, to present female scientists examples, encouraging instructional activities requiring problem-solving, discovery, hands-on involvement, pushing for collaborative and cooperative group activities, student-centered discussion and sharing of ideas. Moreover, we adopted a gender-equitable language, assumed ample wait time for the free discussion and avoided any kind of competition.

An unexpected difficulty in the project implementation was the presence in some groups of children with very different Special Education Needs (SENs). We had one boy with a form of Autistic Spectrum disorder, a boy with physical motor impairment, one girl probably gifted, three foreign students with some language difficulties. We hence tried to adapt any educational unit to their needs, changing approach from time to time and trying to engage them in a collaborative learning environment.

To evaluate the effectiveness of the project, we use qualitative methods using interview scales of competence and enjoying pre and post-activities, drawings analysis, teacher interviews. We also video-recorded all the meetings held, in order to examine the nature and content of the performed activities. All the qualitative results of the project are still under valuation and they will be the subject of a future paper.

2.5 The project evolutions.

The project is, for its own nature, extremely flexible and adaptable to different astronomical (but not only) contents. Having a simple story telling structure based on Blue curiosity and questions, it is very simple to propose an evolution of the project (new Blue adventures) following the modules scheme or expand to some specific activities.

With one class having only children aged 5 years, we designed and implemented an additional activity devoted to the introduction to the computational thinking. Children were invited to plan a space mission to recover Blue – lost in the Solar System – and bring it back to Earth. The mission was conceived, programmed and carried out with the programmable toy Cubetto © PrimoToys, a very simple tool easily usable by young children.



Fig. 6: Parents explore constellations created by children.



Fig. 7: Paper-machine Sun and planets.



Fig. 8: Quiz for parents.



Fig. 9: Athletic team games.

As a project by-product, the stories of Blu are becoming an interactive e-book easily distributable in different formats and accessible from different operating systems and devices (multidevices). The e-book, designed by a professional Instructional designer, Alessia Luca, follows a Learner-Centered approach that takes into account the needs of the reader, is accessible and inclusive as it adapts to the needs and difficulties of the reader, making it possible to overcome the barriers of reading for certain types of learning disabilities such as dyslexia. The text, formatted with specific characters and layouts for dyslexia, is usable both in Read Aloud mode and in CAA (Augmentative and Alternative Communication) thanks to the transposition of the texts into WLS (Widgit) symbols and it is hence suitable as a pre-learning tool for young children and/or as a compensative instrument for children with autistic spectrum disorders. The final product will be completed by multimedia contents to be downloaded, such as the printable version of the story, cards for educational activities and the audio book, and it will be easily upgradable and expandable for future uses.

The entire project, including produced materials, is available – in Italian – at this *link*.

3. Conclusions

People think that kindergarten prepare children for next school grades, i.e. for reading, writing and math. It is certainly true, but kindergarten also prepares children to develop a scientific thinking and to understand scientific principles. In summary, it prepares them to become conscious future kids and adults. It is hence of extreme importance to introduce science principles and thinking from very first school levels.

In this work, we design and implemented a pilot educational project for kindergarten, testing the use of cooperative learning method and metacognitive strategies, together with an active and ludic approach. The qualitative evaluation of this project is still in progress, but preliminary results show the importance of some good teaching practices:

- **Use of Universal design for learning principles** to design an educational project: Representation (teachers/tutors should use different forms and tools to explore information); Action and expression (teachers/tutors should offer different way to interact with material); Engagement (teachers/tutors should encourage children to make their own choices and follow their interest)
- **Use of cooperative learning.** Good learning is collaborative and social, not competitive nor isolated. The use of cooperative and collaborative learning and the sharing of one's own ideas and problem solving strategies often increases involvement in learning and deepens understanding.
- **Importance of respecting diverse talents and ways of learning.** The road bringing to knowledge is not unique. Students can manifest different talents and styles of learning and hence they should be pushed to learn in new personal ways. It is important to offer flexibility in the ways students access material and explore specific contents, engage with it and think about it.

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References

- Andre, T., Whigham, M., Hendrickson, A., & Chambers, S. (1999). Competency beliefs, positive affect, and gender stereotypes of elementary students and their parents about science versus other school subjects. *Journal of Research in Science Teaching*, 36, 719–747.
- Bonwell, C.; Eison, J. (1991). “*Active Learning: Creating Excitement in the Classroom*” AEHE-ERIC Higher Education Report No. 1. Washington, D.C.: Jossey-Bass. ISBN 978-1-878380-08-1.
- Dewey, John (1910). “*How we think.*” Boston: D. C. Heath and Company.
- Gardner, H. (1983), “*Frames of Mind: The Theory of Multiple Intelligences*”, Basic Books, ISBN 978-0133306149
- Jbeili, I. (2012). “The effect of cooperative learning with metacognitive scaffolding on mathematics conceptual understanding and procedural fluency”. *International Journal for Research in Education (IJRE)*, 32, 45-71
- Koch, J. (2007). A gender inclusive approach to science education. In D.M. Sadker & E.S. Silber (Eds.), *Gender in the classroom: Foundations, skills, methods, and strategies across the curriculum* (pp. 205–223). Mahwah, NJ: Erlbaum.
- Piaget, J. 1957 “*Construction of reality in the child*” London: Routledge & Kegan Paul.
- Scantlebury, K., & Baker, B. (2007). “Gender issues in science education research: Remembering where the difference lies.” In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 257–285). Mahwah, NJ: Erlbaum.
- Slavin, R. E. (1995), “*Cooperative learning: Theory, research, and practice.*” Boston: Allyn & Bacon.
- Terhart, E. (2003), “Constructivism and teaching: A new paradigm in general didactics?” *Journal Curriculum Studies*, 35(1), 25-44.

Astronomy for DEAF: The challenge of a reinvention

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Abstract

The learning of astronomy among deaf people in Brazil is currently a remote possibility: it hardly happens and, as it happens, is generally very limited. Improving astronomy education among deaf children and young people would need to act on four points that would positively impact deaf learning: (1) better align Libras resources (sign language) with astronomy vocabulary needs; (2) to develop didactic solutions more suited to the specific sensory experience of the deaf – both in pedagogical methods, as well as in communication techniques and narrative construction; (3) strengthen teacher training; and (4) rethinking the organization and dynamics of the classroom. These are the aspects that we consider important for the diffusion of astronomy in the deaf children and youth population, which we seek to discuss in this article. Always with the conviction that astronomy plays an essential role in giving the deaf's educational base more quality and introducing them more efficiently and motivatingly into the foundations of scientific knowledge.

Keywords

Astronomy; Libras; Deaf; Learning; Education

1. Introduction

Astronomy is a study subject with high potential for attracting and developing interest in science among children and adolescents. This power of its involvement is largely due to the myths that have formed about the things of the Universe and its

mysteries in the contemporary world. This was mainly from the epic of space travel that began in the middle of the last century and has been greatly amplified with the expansion of electronic and digital media in recent decades. For deaf children in particular, this motivating and educating role of astronomy is very relevant. On one side we have the magical visual dimension of this science – with the stars, nebulae, galaxies, planets, etc. – and on the other hand we have the natural overvaluation of the sense of sight among the hearing impaired. The visual richness of the Universe and the visual ability compensatory approach, giving motivational power to astronomy in the challenge of scientific initiation of deaf children and adolescents.

The biggest problem with teaching deaf astronomy is the lack of signs in Libras, their official language. Signs are missing that correspond to the needs of astronomy, whether descriptive of objects or narratives of phenomena. This is the first and greatest obstacle to transmitting information and knowledge about the Universe and its dynamics through Libras. On the other hand, this language has a very strong emotional connection with the deaf, because it is with it that they build their identity and also the —deaf culture. That is, it is necessary to dive and live in the environment of Libras, to identify links of expression and motivation that bridge the gap between deaf people and the passionate science of the stars. A challenge that deserves to be lived, because astronomy, like all science, is constantly evolving and therefore arouses people's sense of curiosity, stimulating the human impulse to know the origin of the Universe. And we think it is important to harness this power of attraction for the benefit of a deaf-friendly scientific initiation, with a likely positive impact on their education and socio-economic inclusion.

2. Missing signs

Libras – the Brazilian Language of Signs – is the official language of the deaf in Brazil. It is fully articulated through signs, having its own structure and rules. It is characterized by a set of gestural forms used by deaf people to communicate each other, or with hearing persons initiated in this code. Linguistically, deaf expression features have a fundamental difference: whereas the language of the listeners is oral-auditory and based on phonemes that are emitted to form words, the language of the deaf (Libras) is visual-gestural. It arises from the combination of hand movements and pivot points, which are local in one's own body or space, where the signals are made. Libras also includes the use of facial and body expressions, thus setting up a linguistic system for conveying ideas, facts and emotions (Figure 1).

Teaching astronomy to deaf students is a challenge because it faces a clear limitation in Libras, where the lack of science-related signals is notorious. In the case of astronomy, for example, there are no signs for Pluto, Ceres, light years, supernova, heliocentricity, ultraviolet, star cluster, reflection nebula and emission nebula, among many other fundamental designations within the study of stars. In fact, as knowledge and teaching of astronomy are incipient in the deaf community, the language of Libras has come to incorporate only a small number of designations of Universe-related elements or phenomena — such as the Sun, Moon, planets, eclipse, and stars. They are more familiar to common sense. Therefore, scientific comprehension is lacking in the language of Libras.

In order to compensate for this deficiency there is a special typology, a kind of manual alphabet for the deaf. In this alphabet, each letter of the written portuguese language has a corresponding sign (Figure 2), used to spell or —type the words letter by letter with the hand signs. Deaf people use this tipololy to —write names of people, streets, objects and a multitude of words not contemplated in sign language. However, this manual alphabet is a pedagogical hindrance and does not replace the significant force of Libras, which has its own lexicon involving the sign itself and the emitter's gesture (Brazilian Confederation of the Deaf, 2009).



Fig. 1: Libras is the second official language of Brazil, recognized by Law N^o. 10,436, of April 24, 2002 (BRAZIL, 2002) Photo: unknown.



Fig. 2: Typing or manual alphabet. Source: Rio Branco College.

3. Innovation in signs and methods

A lot of strategic words in astronomy have no corresponding signs in Libras, and in order to improve the effectiveness of deaf astronomy teaching, new and specific signs will be needed to make it easier to understand at least the foundations of star science, as the subject matter is specialized. This is a concrete experience of one of the authors of this article (Xavier), who is also deaf, who in giving lectures on astronomy in Special Schools of the Deaf sought to create new signs and combine or adapt existing signs to better make their presentations possible. Among the solutions he developed are signs for neutron star, galaxy, Mercury, Mars, binary star, among other signals.

Although many astronomy strategic words have no match signs in Libras, the proposal is to develop not only new signals, but also innovative teaching resources, mainly aimed at understanding the phenomena and dynamics of the Universe. In this horizon, it is worth remembering that the sense of sight is an important compensatory resource for the deaf. Scientists at Sheffield University in England, for example, have observed that people born deaf or who have lost their hearing have better peripheral vision, which is related to differences in the distribution of retinal nerve cells. According to British scientists, this allows them to see more objects at the extremes of the visual field and thus have a better perception of the external environment. (DAVIS, 2010)

Then the astronomy teaching can explore a pedagogical and didactically curricular framework best suited to this deaf strength in order to provide methodologies that take better advantage of its cognitive advantage in vision. A concrete example of this adaptation to the deaf sensory reality can occur in content with high visual information potential, for which the use of images, animations, infographics and videos in the classroom should be valued, increasing the degree of understanding of the subjects. Images are essential tools to facilitate deaf learning, particularly with regard to astronomy. From this perspective, some contents stand out, such as observation and mapping of its, measurement and coordinate system, astronomical instrumentation, deep sky objects and special technology, among many other themes.

Practical and playful activities are also essential tools for the teaching of astronomy for deaf students, as they involve the sense of sight more and significantly compensate for their hearing limitations. In this way they capture attention better and facilitate learning. For example, a basketball and a tennis ball can represent, in scale, the Earth and the Moon, respectively. Fixing the tennis ball at one point and about 6.5 m away from the basketball creates a very didactic and scale simulation of the actual distance between the two celestial bodies, which averages 384,421 km.

4. The ideal master: a challenge

In any teaching activity, the human factor is decisive for the effectiveness of learning and the teacher thus becomes the engine of good learning. This is even more sensitive in didactic actions with deaf people, because one of the pillars of communication, audio, is absent and needs to be compensated in some way. In addition, Libras is not the natural habitat of a listening teacher, a situation that tends to be more frequent the more specialized the subject of teaching, as is the case with astronomy. The following is an example of three didactic environment situations, common in the deaf teaching-learning process.

- **Deaf students x Listening teacher x Pound interpreter:** First, a classroom with a listening teacher, some deaf students mixed with listening students and a Libras interpreter – in a regular listening school (Figure 3). It is a situation that divides the student's attention, because the teaching action is mediated by the interpreter and this increases the potential for information dispersion and



Fig. 3: Classroom with listening teacher, hearing impaired student and Libras interpreter, there is bipolarization of student attention due to mediated action. Photo: Adriana Horvath, 2019.

misalignment between teacher and interpreter. In this classroom setting, the interpreter should be aware that he is not the teacher and should be limited to the communicative functions of his role, without interfering with the pedagogical area, maintaining the impartiality of his profession and developing a healthy relationship with deaf students and the body teacher.

- **Deaf students x Listening teacher:** Listening teacher and deaf students in Special Schools. In most of these situations, listening teachers are not fluent in pounds, which affects learning performance to some extent. To counteract this problem, the educator needs to master sign language.
- **Deaf students x Deaf teacher:** In the classroom with deaf teacher and deaf students, the focus of attention will be only on the teacher (Figure 4). In this circumstance, there is a tendency for greater teacher mastery in Libras and better linguistic interaction between students and teacher.

Several aspects are at stake in the deaf learning process – such as the teacher’s degree of knowledge, his / her didactic experience, sensitivity to students’ difficulties, communication skills, group integration and commitment to results, among other factors. However, experience has shown that hearing impaired people with a solid background in a particular subject better teach other deaf people, precisely because they have a more consistent mastery of Libras and can better deal with students’ hearing impairment and their influence on their behavior.

5. Portal and potential multiplier

In 2017, in Brazil, the portal —Astronomy in Libras| was created on Facebook and Youtube, dedicated to commenting on studies and discoveries of astronomy for the deaf public in particular, also reaching the lay public in general. As of November 2019, this portal, created by one of the authors of this article (Xavier, 2017a, 2017b), already had 166 videos with information about celestial bodies and Universe phenomena, all in the language of Libras. It has also been demonstrating how differentiated strategies and forms of communication can be established to attempt a more effective connection with the deaf audience (Figures 5 a/b/c). —Libras Astronomy| also demonstrates how new sign development can be attempted and tested, then gradually fixes them among its deaf audience. This is true of the signs already mentioned earlier in this article, as well as others to designate black hole, Venus, Uranus, galaxy. For now it is a small step, considering that much remains to be done, but demonstrating that there is space and people dedicated to this challenge.

According to Langhi and Nardi (2012), one of the multiple attributions of astronomy is to promote interest and appreciation for science in people. This is because astronomy usually raises questions that arouse curiosity, such as the functioning of the Solar System, the cause of the phases of the Moon, the nature of supernovae, the threat of comets and so many other subjects that stimulate people’s imagination. Therefore, astronomy education has excellent motivating and educational potential for children and young people, and it is also important and inclusive to open this door of knowledge for the deaf, for students, teachers and society, because —Astronomy is especially suited to encourage students to deepen knowledge in a variety of areas, as their teaching is highly interdisciplinary. (Langhi; Nardi, 2012, p.108)

6. Conclusion

The teaching of astronomy for deaf children is still incipient, although its contribution to their education is very relevant, especially for their better insertion in the



Fig. 4: Without mediation, the Libras class, with a deaf teacher, allows direct transmissions, allowing focus of attention and greater interaction. Photo: Charles de Moura / PMSJC, 2018.

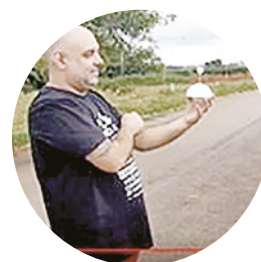


Fig. 5 a/b/c: Teaching experiences of the portal —Astronomy in Libras: a) comment on binary star with support of Styrofoam balls; b) teaching about the nucleus of a star; c) scale demonstration of the distance from the Sun to Jupiter. Source: Astronomy in Libras, 2019.

science context. In order to improve the penetration of astronomy in the Special Schools, the challenge of working and improving the Brazilian sign language must be overcome first, aligning it better with current concepts, vocabulary and narratives in the science of Universe. How to do this? Seeking to develop new signs and syntaxes within this language.

It will also be critical to develop pedagogical resources and methodologies that explore the comparative advantages that deaf people develop in ways other than hearing, especially vision. In other words, besides new signs, it will be fundamental a didactic repositioning of the subjects and supports involved in learning, making it more friendly and easier for the deaf, through the greater use of images, infographics, videos and digital tools. Much can be done to improve deaf learning support in both technology application and didactic innovation.

Finally, special attention needs to be paid to teacher education, supporting deaf teachers interested in solidifying knowledge of astronomy and other sciences. For example, by creating incentive programs for deaf elementary school teachers, encouraging them to take new degrees or special continuing education courses. As for the mastery of Libras, it can also be encouraged with specific actions aimed at listening teachers.

The primordial consciousness in this matter of deaf formation in astronomy is even broader. In fact, it is related to the goal of increasing the efficiency of science learning among the hearing impaired, as this is socially responsible, including and generating well-being and wealth, in the future.

References

- Brazil. Law n°. 10.436, April 24, 2002. Provides on the Brazilian Sign
- Language – Libras and makes other arrangements. *Official Diary of the Union*, Section 1, January 25, 2002, p.23, Brasília/DF. Available in: http://www.planalto.gov.br/ccivil_03/LEIS/2002/L10436.html Access in: 27 jan2017.
- Brazilian Confederation of the Deaf. Homepage, 2009. Available in: <http://www.cbsurdos.org.br> Access in: 09 nov 2016.
- Davis, S. *University research reveals deaf adults see better than hearing people*. Scientists At Sheffield University. 2010. Available in: <https://www.sheffield.ac.uk/news/nr/1798-1.174138> Access in: 29 nov 2019
- Horvath, A. *Scientific American Brazil*. 2019. Available in: <http://sciam.uol.com.br/curso-de-astrobiologia-para-surdos-expande-linguagemcientifica-em-libras/> Access in: 29 nov 2019.
- Langhi, R.; Nardi, R. *Astronomy Education: Rethinking Teacher Education*. Science Education, vol.11, São Paulo: Scriptures, 2012.
- Moura, C. *São José do Campos City Hall*. 2018. Homepage. Available in: <https://www.sjc.sp.gov.br/noticias/2018/setembro/15/escola-de-sao-jose-ereferencia-na-educacao-de-surdos/> Access in: 29 nov 2019.
- Rio Branco College. Homepage, 2019. Available in: <http://www.ces.org.br/site/Default.aspx> Access in: 29 nov 2019.
- Xavier, B. *Astronomy in Libras*. 2017a. Facebook. Available in <https://www.facebook.com/groups/222858628255607/> Access in: 11 dez 2017.
- Xavier, B. *Astronomy in Libras*. 2017b. Youtube. Available in: https://www.youtube.com/channel/UCzz4LAXwd3n_8v1zvmevHIQ?view_as=subscriber Access in: 11 dez 2017.

Why are you going to Tamra?

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Abstract

The story you are about to read is written intentionally in a narrative style and voice to align with the nature of the presentation made at the conference. This paper is the intersection of stories from my lived experiences intended to accentuate the challenges associated with integrating cultural and religious knowledge about the cosmos, more formally captured as ethnoastronomy, into astronomy education. For transparency, this presentation did not emerge from a research study, nor was it designed as a report on findings derived out of empirically collected data. Like the conference presentation, this paper emanates from the theoretical frame of autoethnography. The nexus of this story is situated as my daughter and I were connecting flights from our home city of Winnipeg en route to Tel Aviv where the head of security for an Israeli Airline at Pearson International Airport in Toronto, Canada asked us, “why are you going to Tamra?”

1. Introduction

That question, and the forty-five minutes we were interviewed at this intermediate security checkpoint, was done for security reasons. I understood the need for increased security prior to boarding a flight for the Middle East as there had been a recent increase of terror in Gaza as riots were marked by an escalation of violence between Israel and Hamas (Kocsis, 2019). Gaza, also known as the Gaza Strip, is a Palestinian territory on the eastern bank of the Mediterranean Sea that borders Egypt and Israel. We were not going to Gaza, but rather Israel.

The primary question of our travel plans, however, had an undertone. Why were ‘you’ – as in me, a Canadian Jewish man and his twelve year old daughter, going to Tamra, an Arab city in Israel. The questions that followed included: What could I possibly be doing there, and how would I know anyone from there well enough such that we would be welcomed guests in their home? The answers I provided the officers were truthful and innocent: we were going to see our friends, who are Arab, and we were going to continue working on using astronomy education as the locus for breaking down societally imposed barriers.

After declaring that I was simply a professor, and not a spy, nor worked for an undisclosed branch of government, and was not trading state secrets with the Arab community – an item in my book bag provided the eventual passageway through security. I was fortunate to have a copy of *The Physics Teacher* Volume 55 Issue 6, as it contained the article Nayif (my Arab friend and colleague) and I cowrote (Hechter & Awad, 2017) about using ethnoastronomy in classrooms and in society to connect people and the human spirit under the night sky. I was taking the hard copy to him as I had ordered extra copies. In desperation, I handed it to the officers for their perusal

as an attempt to verify who I was (and was not), and why we would be welcome in Nayif's home despite our religious and cultural differences.

Surprisingly, given the volume and complexity of the other questions I answered, this was enough to convince the officers to let us pass through. With our stamped boarding passes, we were ushered to the main security checkpoint and proceeded as unspecific passengers towards our departure gate.

After safely storing our carry-on items in the overhead bins and beneath the seats in front of us, we settled into our seats for the 11 hour flight. Waiting for the push back from the jet bridge, I reflected on the previous interaction. It occurred to me that there were only three possible reasons for this elongated interview regarding why we would be going to Tamra. They were: a) that we are Caucasian, b) that we are Canadian, and c) that we are Jewish.

Living in Canada, where dedicated efforts are now being realized to reconcile othering (Jensen, 2011; Schwalbe, 2000) of Indigenous people, the colour of our skin makes a difference with regard to the unearned privileges we are afforded. Being a Canadian citizen and thus holding a valid Canadian passport, has significant privileges, especially when travelling globally. As collated by the Henley Passport Index, a Canadian passport is ranked 6th as the "most powerful passport to hold" in the world. Canadian passports allow for greater international access with minimal effort as our passports enable visafree access to 184 destinations (McKirdy & O'Hare, 2019). This is a privilege, and reflects a global power structure with an inherent racist bent that defines and ranks countries for safety, compatibility, and peace. As such, an abundance of travel and opportunities are possible due to being Caucasian and having a Canadian passport.

None of the aforementioned reasons, however, was the actual reason for our detainment. Unfortunately, it was the third option that outweighed the rest: we were Jewish and we were making a deliberate stop in our travel itinerary to a known Arab city in the northern part of Israel. For some, this is problematic and violates social norms and invisible borders, as unlike in the Gaza and some other restricted areas of Israel, there are no physical barriers to get into Tamra. For these people, our interfaith relationship with Nayif's family infringes upon past and current generations' philosophical worldview of hierarchical ranking of people based on culture and religion. At its source, it is the self-determined inclusion and exclusion of people based on self and others.

2. My background

I have had the good fortune of travelling the world, including to Israel, Iceland, United States, South Africa, England, and Germany, to continue my work of using astronomy as a vehicle to cultivate empathy and hope amongst people of diverse cultural and religious backgrounds. One interesting component of this list is that Iceland and Germany are largely ethnically and culturally homogenous – which made my visits to, and work to minimize othering in these places that much more impactful, albeit in a different way.

Using commonly known constellations and asterisms, and more regional phenomena like the northern lights, I have explored the intersection of people, place, culture, and astronomy through a focussed ethnographic framework (Knoblauch, 2005). At its most pragmatic level, I share experiences with people and listen to their stories of how the sky resonates within them. The stories range from teachings, to warnings, to mythology, and purposeful beacons of established knowledge. More often than not, the stories I am told are a beautiful confluence of several of these elements. Sometimes, but only with their permission, I share other peoples' stories to help make the sky come alive. Mostly, however, I keep the starlore and mythlore that radiates in these sacred stories within me

to both honour their words, but more importantly, to honour their trust in me.

After hearing the whir of the engines and feeling the thrust of the plane as it rumbled down the runway for takeoff, we departed on our journey. I sat back in my chair only to realize that the seemingly isolated event at the airport's security counter moments earlier was in fact a microcosm of the primary challenge when integrating ethno-astronomy into mainstream astronomy education: racism.

3. Challenge One: Racism.

Regardless of where I am, and with whom I am sharing my experiences with, be it a conference, an invited talk, or a presentation – some people I interact with are still racist. Hierarchical racist structures are embedded throughout society. Equally important to note, however, is that there are also individuals who are not racist, and are not marginalized or discriminated against, but are reluctant to dismantle institutionalized racism that benefits their acknowledged or unspoken unearned privilege. Either way, I believe racism is a learned behaviour, and is therefore one that has the potential to be changed.

Earlier in summer 2019, when delivering an invited talk at the Institute of Physics to a packed house in London, England, I had just finished describing how I met Nayif, how we became friends, and how we are trying to change the world through physics education. Almost on command, an interested audience member blurted out an anti-Semitic comment. It seemed as though he did not like that I was Jewish, which I had proudly declared moments earlier. Further, he was enraged that I could be friends with an Arab. Having been a teacher for over 21 years from the high school level to teaching in post-secondary, experiencing hecklers in the crowd was nothing new or concerning for me. Using my best 'teacher' approach, I offered to meet with him after the talk to answer any and all questions he might have. This was my attempt to dampen his hostility and diffuse the situation. It worked. Briefly. What was amazing is that he interrupted with punishing comments at what was seemingly the perfect moments throughout the next eight minutes. The Institute of Physics staff were on top of this quickly and quietly intervened, but I waved them off as I felt I could handle this.

As I made one final offer to this individual to cease his comments in exchange for being first in line to the appetizers and wine which was waiting for us at the post-talk reception, I looked around the room and read people's faces. It seemed that some of the other audience members thought he was a plant. They imagined that he was with me (he was not, my daughter was), and was an intentional part of the talk instructed to object to my claims of using the awe of the constellations to unite people from different cultures together. With one final comment made to another audience member who asked him to cease and desist, I assured him that the threshold of my patience had now been crossed. While uttering more racist hatred, he packed up and left the lecture hall to the applause and jubilation of the crowd. I tried to treat him with dignity and respect, but his comments were clearly racist, offensive, and unwelcome. At this moment, people realized he was not part of the talk, and sadly, he epitomized exactly what I was talking about.

We live in a critical, often unfair, and divisive world that has a dark underbelly of hatred towards those who are not like "us". There is a resurgence of global anti-Semitism (B'nai Brith, 2019; Lubell, 2019; Walt, 2019), and hate crimes in general (Guterres, 2019). This trend not only needs to stop, but needs to begin to revert in the opposite direction. It is one of our duties in education, regardless of the discipline or genre we teach, to educate students in social justice and social responsibility. I pursue this through astronomy education because this is the area of my passion. I am in awe of the sky, and recognize that the sky has no borders, either real or artificially contrived. In short, the sky belongs to everyone. In declaring this, and in my autoethnographic way of telling this story, I am often asked why I do this. This is a very good question.

The roots of this for me are two-fold. First, anti-Semitism is a discrimination that plucks deeply in the chords of my being. Second, I live in Winnipeg, the home of the Canadian Museum for Human Rights. Upon entry to this museum, scripture from the Universal Declaration of Human Rights (United Nations, 1948) is printed on the wall to read, “All human beings are born free and equal in dignity and rights”.

Unfortunately, in Canada and abroad, we have failed to uphold and protect the freedom and equality the Declaration of Human Rights espouses. As Canadians, we are now working to reconcile our past atrocities towards the Indigenous peoples’ who have stewarded the lands’ long before European colonists arrived. The time is now to find ways to make amends for our human rights violations. The time is now to use the power of education to help mitigate hate, divisiveness, ignorance, and discrimination.

The opposition to integrating cultural knowledge of the sky into physics education often manifests due a racist structure that provides a safe space for people who are reluctant to change the status quo that benefits them. The constellations that are taught in schools are the apparent human-determined linking of specific stars to create an imaginary image. There are no connecting lines in the sky that outline these shapes, yet we seem to only identify the constellations from one perspective. Who decided what the “official” constellations would be? Whose voices mattered when deciding this? Whose voices were absent from that decision making table? Given these big questions, especially in terms of curriculum design and content, I arrive at the second major challenge encountered while pursuing this work.

4. Challenge Two: “It’s not physics.”

People all over the world have starlore and mythlore that reveal how the sky, and its celestial constituents, impact their day-to-day life. From farming timelines and indicators, to navigation coordinates and trajectories, the sky is filled with knowledge that is different than what may be construed as standard scientific knowledge. The context of the cosmos provides the vehicle to challenge one’s biases towards multiple worldviews and ways of knowing that vary from modern Western science ways of knowing. To be clear, these views are in no way less valid or authentic. In fact, I invite my students, and anyone attending my talks or workshops, to deviate from the culturally homogenous view of the night sky within an oversimplified Eurocentric lens that is pervasive in our K-12 astronomy curriculum. I am not suggesting entirely replacing the astronomy curriculum with stories emanating out of cultural knowledge. Rather, I am encouraging ethnoastronomy be included as a complement to the existing curriculum such that it provides a richness and deeper context for learners and learning.

We already teach topics like lunar and solar phases. Why not teach them in the context of how different people use the calendar for observance of events and holidays? For example, the Islamic calendar is lunar phase based, the Gregorian calendar is solar phase based, and the Jewish calendar is luni-solar based. What do these mean and how do they work?

As for the constellations we teach students to locate and recognize, why is this only taught through a Western perspective? If you can change the perspective on the free and ubiquitous astronomy software of Stellarium (Chéreau et al., 2001), why would we not do this in our classrooms? For example, the First Nations people in North America (Miller, 1997), the Black South Africans in South Africa (Holbrook, 1998), and the Maori people of New Zealand (Harris, Matamua, Smith, Kerr, & Waaka, 2013) all have starlore that is comprised of stories that are unrelated to the stories found in Greek mythology. Yet, despite having culturally diverse classrooms in each of those locations, we only teach the mythlore of the constellations through one lens.

My suggestion, as proposed in my presentation, and in my work overall, is to identify

the global citizenship that exists in classrooms, and communities, and design and deliver a relevant curriculum. Theoretically underpinning this claim is the belief that cultural knowledge can improve Eurocentric science (Aikenhead & Michell, 2011) by providing even greater depth and perspective to our overall understanding of the night sky. For me, this seems so obvious. Yet the refrain from some, and the second main challenge I experience in integrating ethnoastronomy into astronomy education, is that, “it’s not physics.” This point is made to me often, and I hear you.

In Johannesburg, South Africa at the International Conference of Physics Education, I delivered my keynote talk focussing on the power of ethnoastronomy education in such a divisive and multicultural world. Afterwards, in the question and answer period, a fellow from the back of the main conference room made sure I knew that what I was saying was rubbish, and I was a disgrace to the field of physics. He re-iterated several times that cultural insights of the night sky was not physics, and had no place within it. So let me be clear: no, it is not. It is not the physics and astronomy you may have learned in K12 and post-secondary levels. It likely is not the way of describing the Universe that has systematically been selected as the basis for education in English speaking countries. And no, it is not standard for all, measurable, and objective – all tenets of modern Western science and physics.

What it is, however, is personable and border-free. It is inclusive, and relevant for all. It opens the opportunity for students to see themselves in the curriculum. It initiates conversations about knowledge, how it is passed along generational lines, and how the position of the stars can provide much more than a horoscope found in the newspaper. Celestial position can inform people about when it is time to harvest the crop, where to steer your vessel to navigate in the open water, or where to look to see the ethereal beauty of the aurora. It might be the spirits of ancestors who have gone west, or a tribute to animals, or a blessing from Mother Earth. What it is, at its finest point, is the inclusion of context and perspective into something that belongs to everyone. So, no, it is not ‘physics’ in the way many of us have taught and learned. Rather, it has the potential to be personal, meaningful, and impactful in a different yet equally authentic way.

5. Conclusion

Ella, my daughter, and I journeyed to Israel, and midway through our trip we found our way to Tamra. Spending quality time with friends, visiting a local school and university, and sitting on Nayif’s rooftop to look at the stars cascading over the Mediterranean Sea made the delay at the security counter in Toronto a forgotten memory. That was, of course, until we were encouraged to cut our planned visit to Acre, a predominantly Arab town just north of Haifa, as riots were overtaking the community. This time, however, the riots did not threaten us because we are Jewish. Rather, it was because our visit coincided with United States President Donald Trump initiating the move of the United States embassy to Jerusalem from Tel-Aviv, while simultaneously declaring Jerusalem as the undisputed capital of Israel. These

actions incited violence against foreigners, especially those from North America. While being Canadian has its benefits while travelling abroad, our home country is only known to others by looking at our passports. We look and sound North American which often does not distinguish Canadian from American, and given the announcement from the White House, that was dangerous for us. We adjusted our travel plans and arranged to spend the remaining time in Israel in the secular part of Tel Aviv to avoid as best possible the danger areas identified in the news.

In Israel, like in Canada, systemic and institutionalized racism still exists, often in unconscious ways. Unfortunately, these deeply rooted positions can inhibit people from caring for others as equals and as neighbors. Furthermore, these positions be-

come the roots that foster the construction of literal and figurative borders to create inclusive and exclusive lists for hierarchical purposes.

Late on our last night we found our way to the airport and boarded the 2 AM flight home. After 10 days in Israel of pursuing my scholarship, enjoying sightseeing opportunities, and eating street falafel in pita, we also went to Tamra. We are thankful and caring for our friends of another culture and religion. At the heart of this visit was my dedication to do my part in mitigating the uprise of divisiveness in our world. I do this by creating opportunities for people to learn, connect, and belong with others of all backgrounds under the majesty and beauty of the night sky. Although this may not be perfect, or for everyone who teaches astronomical phenomena, for me, this is doing my part to make this world a better place.

References

- Aikenhead, G., & Michell, H. (2011). *Bridging cultures: Indigenous and scientific ways of knowing nature*. Don Mills, Ontario, Canada: Pearson Education.
- B'nai Brith. (2019). Canadian Jews most targeted group for third year in a row. *B'nai Brith Canada*. Retrieved from https://www.bnaibrith.ca/canadian_jews_most_targeted_group_for_third_year_in_a_row
- Chéreau, F., Meuris, J., Wolf, A., Chéreau, G., Zotti, G., Cardinot, M., Lambermont, H., & AlAjaji, K. (2001). Stellarium (Version 0.19.2) [Software]. Available from <https://stellarium.org/>
- Guterres, A. (2019). Secretary-General's statement on intolerance and hate-based violence. *United Nations*. Retrieved from <https://www.un.org/sg/en/content/sg/statement/2019-04-29/secretary-generalsstatement-intolerance-and-hate-based-violence>
- McKirdy, E., & O'Hare, M. (2019). World's most powerful passports revealed. CNN. Retrieved from <https://www.cnn.com/travel/article/henley-index-world-best-passport-2019-intl/index.html>
- Harris, P., Matamua, R., Smith, T., Kerr, H., & Waaka, T. (2013). A review of Māori astronomy in Aotearoa-New Zealand. *Journal of Astronomical History and Heritage*, 16(3), 325-336.
- Hechter, R.P., & Awad, N. (2017). Living ethnoastronomy: Discovering the connectedness of the human spirit beneath the night sky. *The Physics Teacher*, 55(6), 369-370.
- Holbrook, J. C. (1998). African Astronomy. *National Society of Black Physicists Annual Day of Scientific Lectures*, 25, 79-81.
- Jensen, S. Q. (2011). Othering, identity formation and agency. *Qualitative studies*, 2(2), 63-78.
- Knoblauch, H. (2005). Focused ethnography. In *Forum qualitative sozialforschung/forum: qualitative social research* (Vol. 6, No. 3).
- Kocsis, M. (2019). The Gaza Riots. *The Journal of Intelligence, Conflict, and Warfare*, 2(1), 7-7.
- Lubell, M. (2019). Anti-Semitic attacks rise worldwide in 2018, led by U.S., west Europe: study. *Reuters*. Retrieved from <https://reut.rs/2WeOpyR>
- Miller, D. S. (1997). *Stars of the first people: Native American star myths and constellations*. Westwinds Press.
- Schwalbe, M. (2000). The elements of inequality. *Contemporary Sociology*, 29(6), 775-781.
- United Nations. (1948). Universal declaration of human rights. Retrieved from <https://www.un.org/en/universal-declaration-human-rights/>
- Walt, V. (2019). Europe's Jews are resisting the rising tide of anti-Semitism. *Time Magazine*. Retrieved from <https://time.com/longform/anti-semitism-in-europe/>

Fifteen years of PETeR, an educational project with robotic telescopes in Spain

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Abstract

PETeR is an educational project of the Instituto de Astrofísica de Canarias (IAC) which aims to engage Spanish students in science and to encourage them to acquire STEM skills through their active participation in guided research projects in Astronomy using robotic telescopes. The project started in 2004, following the installation of the 2-m Liverpool Telescope at the Roque de los Muchachos Observatory (La Palma, Canary Islands). This paper outlines the conditions that allowed the implementation of the project in the first place and how has been the process of redesigning the project to its current format. This is followed by a description of the project goals, materials and educational approaches used, as well as the teacher training programs that we run in the framework of the project. It concludes with some of the evaluation results and a discussion of the main challenges identified by the project coordinator and participating teachers.

Keywords

Astronomy education, robotic telescopes, science education, technology in science education, astronomy, Student Astronomy Research

1. Introduction

In many European countries student interest in STEM (Science, Technology, Engineering and Mathematics) careers is low [1], which has led to a growing concern about possible mismatches between demand and supply for qualified STEM professionals in Europe [2]. The challenge that many educational systems are facing is, therefore, how to encourage students to acquire STEM skills, and how to increase the number of young people who want to develop their future careers as professionals in the fields of technology and research. A study [3] carried out on more than 2500 Spanish secondary school students shows that they attribute their lack of interest in STEM studies to the way these subjects are taught in schools, their complexity and the apparent lack of sufficiently attractive professional opportunities. Thus, the challenge of engaging students in these areas involves working with teachers as well,

providing the latter with the resources and means necessary to develop a more appealing and stimulating STEM education.

Astronomy is the perfect engine to arouse curiosity and interest in STEM subjects, from children to adults [4]. It unites the ancestral human longing to know what is beyond the world that surrounds us with the ‘wow’ effect produced by the images of the Universe and the phenomena occurring in it. In the last decades, the implementation of robotic telescopes, designed to work autonomously, coupled with the development of tools that allow their use by non-professional observers, have made it possible to open this science to the participation of the educational community. Robotic telescopes also allow developing an inquiry-based approach to teaching-learning STEM, which translates into a better understanding and assimilation of concepts [5]. Several studies have been published on the use of robotic telescopes for student research and Astronomy education, including a recent review by Gomez and Fitzgerald (2017) [6]. This work analyzed several educational projects, mainly in English-speaking countries, and summarized the principal challenges to the domain overlapping robotic telescopes and education, concluding that both careful project design and deep qualitative research are crucial for the success of individual projects and the progress of the whole field.

The Instituto de Astrofísica de Canarias (IAC) has been running the Educational Project with Robotic Telescopes (known by its Spanish acronym PETeR) for fifteen years. PETeR is an enquiry-based online lab that dedicates observing time with professional robotic telescopes to activities and student research projects aimed at primary and secondary schools (students aged 6 to 18) in Spain [7]. This paper describes the process followed to design the project up to its current form, provides an overview of the challenges that we have identified in its implementation and outlines some of the evaluation results.

2. Background

The IAC is a public R&D center in Astrophysics. It is located in the Canary Islands (Spain) and consists of two headquarters, where research and technology development is carried out, and two observatories, the Teide Observatory (in Tenerife) and the Roque de los Muchachos Observatory (in La Palma), both at about 2,400 meters above sea level. The Observatories of the Canary Islands benefit from an exceptional astronomical quality that place them as one of the three best observatories in the world, together with Hawaii and Chile [8]. For this reason, more than thirty telescopes and experiments operated by institutions from over twenty different countries are located at the Canarian Observatories. These institutions and the IAC sign cooperation agreements under which Spain provides the site and its maintenance and, in return, the owner institutions give Spain a package that includes a certain percentage of the observing time with their telescope.

In 2003 the Liverpool Telescope (LT) was installed at the Roque de los Muchachos Observatory, and went robotic for the first time the year after. It was the first of the 2 meter fully autonomous robotic telescopes, and it is one of the largest and more advanced even today. The LT is owned and operated by the Astrophysics Research Institute of the Liverpool John Moores University, which decided to devote 5% of the observing time with this telescope to astronomy education and outreach in the UK, and for this purpose the National Schools’ Observatory (NSO) [9] was created. The IAC also made a major commitment to science education in Spain deciding to set aside for this purpose 25% of the Spanish time with the LT, which means another 5 % of the total observing time on this telescope. The PETeR project was set up between 2004 and 2006 to manage this pool of educational time on the LT. A coordination position for the project was also created, linked to the Communication and Outreach Department of the IAC.

In its initial phase, PETeR followed the line of its sister project, the NSO, offering its users pre-defined observations of selected celestial objects (the Moon, planets, stellar clusters, different types of nebulae and nearby galaxies), which they could request via a web portal that communicates with the LT. PETeR users also had the possibility of requesting different observations through user-generated proposals that were reviewed by the project coordinator and a panel of experts, who also provided technical and scientific advice when necessary.

The author of this paper, who is the current project coordinator, was hired for this position in 2011. At that time, there were about 70 registered users, most of them schools but also some amateur astronomer associations, and less than 5 % of the available time for PETeR was being used. For an astrophysicist by training it is really surprising that someone has guaranteed access, semester after semester, to a two-meter telescope located at an exceptional site and does not make use of it. What could be hindering the use of the LT by the Spanish educational community? How could we redesign the project to make it attractive to students and teachers and encourage their participation? Attempting to answer these questions was the first objective proposed by the new coordinator when she joined the project.

3. Project redesign

3.1 Preliminary research

The process began with research work on what other educational projects with robotic telescopes were offering and what could be adopted by PETeR taking into account the limitations of the project. In this sense, the greatest limitations were related to human resources and dedication: a single person (the project coordinator) dedicating 50% of a 37.5 hour workweek. Another issue to point out is that until now the continuity of the project has been subject to external funds, which only allow planning for a maximum of two or three years.

Before considering how to redesign the project, we also wanted to gather feedback from the users as well as potential users, so we prepared a quantitative survey and a forum. The survey had two objectives: first, to know the audience; and second, to know what type of project they found most attractive and feasible. The forum allowed us to do a qualitative research on the barriers that the participants identified to implement the project in their centers, to inquire about what their needs would be in relation to it, and also to do a co-creation process on the different options proposed for the project.

The call to participate in the survey and forum, which included information about the project and its possibilities, was announced on the IAC website and on the websites of regional and state educational bodies. Invitations were also sent to registered PETeR users, associations of science teachers in Spain, as well as to amateur astronomers associations. Despite the wide diffusion that we gave to the call, we had a scarce participation. In total, we counted 49 responses, including representatives of schools and associations. The results are described below.

To the question “what would you like PETeR to offer?” the answers were quite spread out. In the case of teachers, 33% of the participants wanted to take part with their students in “real science” projects proposed and designed by professional astronomers, and adapted to the school curriculum; another 33% preferred to work with Teaching Units and activities using archived images; 19% of them chose pre-designed observations, as already offered; and 14% opted for open observing proposals. Amateur astronomers, on the other hand, chose bespoke observations as the most voted option (69%), followed by participation in scientific projects (31%).

As for the barriers that the participants identified to put into practice the chosen options, the teachers highlighted two: their lack of sufficient knowledge in Astronomy and in the specific tools they would need to lead the projects, and that it is difficult to include this type of research-based projects in the formal education processes. In relation to the second issue, time constraints and lack of ICT tools in the classroom were mentioned as the main causes.

3.2 Goals, formats and materials

With all the data collected, the project redesign began. The author started with the revision of the objectives and followed with the formats, resources, actions and web design. The main goals of PETeR were reformulated as follows:

- to stimulate the interest of primary and secondary school students in STEM through their active participation in real research projects;
- to train teachers in Astronomy and in research-based learning methods; and
- to contribute to the diffusion of Astronomy and Astrophysics.

In addition to the pre-defined observations and open proposals that were already being offered, new content was developed and existing content was updated under the active learning approach, attempting to cover most of the community's demands. Five learning scenarios, which had been developed in collaboration with the Museum of Science and the Cosmos of Tenerife and with funding from the Foundation for Science and Technology of the Government of Spain, were revised and updated to offer them to the community through the new project website. Each scenario introduces several concepts related to a topic on Astronomy, and includes one or more practical activities which make use of real astronomical images obtained with the LT. A student-friendly software for visualizing and analyzing astronomical (FITS) images, PeterSoft, was also developed. The software allows obtaining information of the image header in a simple way, as well as measuring angular sizes, distances, and brightness (by doing aperture photometry).

Another approach is the participation in research projects, either proposed by us or designed by the schools themselves. With this approach students can experience the scientific method following the phases of inquiry-based learning [10]. PETeR's coordinator provides orientation in the form of educational materials and technical and scientific advice during the whole process. Collaboration is also an important part of PETeR, with other education institutions and IAC researchers in the design of some of the projects, and promoting the cooperation among schools during their implementation.

With the installation of new robotic telescopes in the Observatories of the Canary Islands, it was also possible to add observation time with them to PETeR. However, not all robotic telescopes offer a user interface that is easily adaptable for educational use. In 2017, Las Cumbres Observatory (LCO), which had recently installed two telescopes at the Teide Observatory, launched the Global Sky Partners program, a call to grant observation time with its 0.4m telescopes to educational organizations and projects around the world. We presented PETeR to the call and were selected as an official Education Partner of the LCO, renewing that status in 2018 and 2019 [11]. Thanks to this program PETeR users have access to telescopes located in several observatories in the Northern Hemisphere (Canary Islands, Texas and Hawaii), but also in the Southern Hemisphere (Australia, South Africa and Chile). Another advantage for the users is that they can schedule their observations autonomously through the LCO observation portal, which offers a simple mode with which many educational projects can be carried out, and an advanced mode for more complex programs.



Fig. 1: Telescopes currently available to the Spanish educational community through PETeR. Top: PIRATE and COAST telescopes, belonging to The Open University, at the Teide Observatory. Middle: The 2.0m Liverpool Telescope at the Roque de los Muchachos Observatory (La Palma). Bottom: In the foreground, two of the LCO's 0.4m telescopes, these at the Teide Observatory (Tenerife). Images credit: Daniel López / IAC.

This tool allows users to enjoy greater freedom of action and enrich learning with decision making that accompanies the selection of observation times, filters, etc. This also relaxes the time that the coordinator has to dedicate to each user, although she continues with the individualized work of advice and resolution of doubts. Since 2019 PETeR users also have access to make observations with the PIRATE and COAST telescopes, which were inaugurated at the Teide Observatory at the end of 2017. These robotic telescopes belong to The Open University (OU) and also have an observation portal for non-professional users [12] that allows easy use in education.

The new project website (www.iac.es/peter) was launched in 2015 and included the new materials and tools developed, as well as updates on previous contents and modes of observation. The web portal has been continuously updated since then with information on the available telescopes and how to request observations with them, news items, images and the incorporation of new tools, such as a “Questions and Answers” forum where users can raise their doubts, check those raised by other users and already resolved, and interact with each other.

3.3 Teacher training

Another key point of the new PETeR is to engage and train teachers in Astronomy and in the use of robotic telescopes for student research projects and inquiry-based learning. With this aim we run several teacher trainings trying to reach different communities. One of our main targets is local teachers, as we aim for the educational community of the Canary Islands to identify the scientific culture and sky of the Archipelago as part of their own heritage. We offer them extensive training along the school year, both in person and online, and in collaboration with the Department of Education of the Government of the Canary Islands.

During the school year, we also run online training sessions for teachers in mainland Spain, organized by PETeR or as part of collaborations with other initiatives, as the CESAR project (ESA). And, since 2015, we organize every summer the international course “Astronomy Adventure in the Canary Islands” in collaboration with other education partners such as NUCLIO, the Faulkes Telescope Project, and the NSO. It consists of a complete week of face-to-face training with a special focus on hands-on activities with robotic telescopes and astronomical images.

The trainings cover the following topics: general concepts of Astronomy, how to observe with the different telescopes available through PETeR, how to use the software for visualizing and analyzing astronomical images, and examples of activities and research projects that can be carried out with the available telescopes and tools. By November 2019 we have trained more than 300 teachers and educators, mostly from Spain, but also from other European countries and the United States.

4. Results

PETeR currently has more than 200 educational users in Spain, most of them secondary schools, but also primary schools and non-formal education centers (science clubs and camps, after-schooling, ...), as well as nearly 20 amateur astronomer associations. PETeR users now consume around 30% of the available observing time, i.e. between 7 and 10 times more than in 2011, taking into account that the amount of available time has increased with the addition of new telescopes. Compared to the increase in the number of users by a factor of 3, we see that, on average, each user is taking between two and three times more observing time than in 2011. This can be explained by the increase in the number of schools that are carrying out authentic research projects with PETeR. Many of these projects are born as a pilot experience



Fig. 2: Inaugural session of the international summer course “Astronomy Adventure in the Canary Islands 2019”.
Image credit: Inés Bonet (IAC).



Fig. 3: Students at the Calero Institute of Secondary Education (Gran Canaria, Canary Islands) and his Maths teacher, Carlos Morales, developing the research project by which they discovered two binary stars. Image credit: IES El Calero.

that is designed jointly by an interested teacher and the PETeR coordinator, tested by the teacher with his/her students, and then reproduced by other teachers and independent students. An example is the research project on variable stars developed in 2017 by a Mathematics teacher, Carlos Morales, who attended the first edition of the “Astronomy Adventure in the Canary Islands”, and his 12 year-old students. They discovered and characterized two binary systems using observations with the LCO telescopes and archive data. These students were the youngest in the world to make such a discovery inside a process of formal education [13]. Afterwards, the project has been carried out in more than ten secondary schools in the Canary Islands.

PETeR currently has more than 200 educational users in Spain, most of them secondary schools, but also primary schools and non-formal education centers (science clubs and camps, after-schooling, ...), as well as nearly 20 amateur astronomer associations. PETeR users now consume around 30% of the available observing time, i.e. between 7 and 10 times more than in 2011, taking into account that the amount of available time has increased with the addition of new telescopes. Compared to the increase in the number of users by a factor of 3, we see that, on average, each user is taking between two and three times more observing time than in 2011. This can be explained by the increase in the number of schools that are carrying out authentic research projects with PETeR. Many of these projects are born as a pilot experience that is designed jointly by an interested teacher and the PETeR coordinator, tested by the teacher with his/her students, and then reproduced by other teachers and independent students. An example is the research project on variable stars developed in 2017 by a Mathematics teacher, Carlos Morales, who attended the first edition of the “Astronomy Adventure in the Canary Islands”, and his 12 year-old students. They discovered and characterized two binary systems using observations with the LCO telescopes and archive data. These students were the youngest in the world to make such a discovery inside a process of formal education [13]. Afterwards, the project has been carried out in more than ten secondary schools in the Canary Islands.

5. Conclusion

The results of this and other similar educational projects have shown that robotic telescopes are very effective tools for bringing STEM areas to students in a practical and attractive way. However, the experience acquired in PETeR’s 15 years of existence leads us to conclude that, in order for this type of project to be generally exploited by the educational community, and not just by a few highly motivated teachers and students, a combination of the following factors is required:

- to design research projects adapted to different educational levels and including a direct connection with the curricular contents, so that their development implies a minimum load of adaptation time on the part of the teachers;
- to provide continuous training to teachers on Astronomy topics and on the use of the available telescopes and the analysis of astronomical images;
- to give scientific and technical advice to the specific doubts of the users;
- to make a periodic evaluation and adapt the project to changes in the educational system, access to resources and other factors that may affect its development; and
- to give wide diffusion to the project and its applications and results.

In order for a project to be able to meet the above needs effectively, it is essential to have a minimum number of staff associated with the project with continuity at least from the design phase to the evaluation and dissemination of results.

References

- [1] European Commission (EC), Eurostat – Tertiary education statistics (2018). ISSN 2443-8219.
- [2] European Commission (EC), Directorate General for Education and Culture – Higher Education (2015). Does the EU need more STEM graduates? Final report. *Publications Office of the European Union*, doi: 10.2766/000444.
- [3] La Caixa Foundation, FECYT and everis (2015). *¿Cómo podemos estimular una mente científica?* Study on scientific vocations. <https://www.fecyt.es/es/publicacion/como-podemos-estimular-una-mente-cientifica>.
- [4] Percy, J.R. (2005). Why astronomy is useful and should be included in the school curriculum. *Teaching and learning astronomy*, edited by J.M. Pasachoff and J.R. Percy, *Cambridge University Press*, Cambridge UK, pp. 10-13.
- [5] Furtak E.M., Seidel T., Iverson H., Briggs D.C (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. *Review of Educational Research*, 82, pp. 300-329, 10.3102/0034654312457206
- [6] Gomez, E. L. and Fitzgerald, M. T. (2017). Robotic telescopes in education. *Astronomical Review*, 13(1): 28–68.
- [7] Rodríguez-Eugenio, N. (2018). ‘Robots looking at the sky’ opening professional telescopes to students. *Proc. of the Communicating Astronomy with the Public 2018*, Fukuoka, Japan, Volume 2, pp. 174-175.
- [8] Vernin, J. et al. (2011). European Extremely Large Telescope Site Characterization I: Overview. *Publications of the Astronomical Society of the Pacific*, Volume 123, Issue 909, pp. 1334.
- [9] Newsam, A. (2007). The National Schools’ Observatory. *Astronomy & Geophysics*, 48(4):4–22.
- [10] Pedaste, M. et al. (2015). Phases of inquiry-based learning: Definitions and the inquiry circle. *Educational Research Review*, 14, pp. 47-61, 10.1016/j.edurev.2015.02.003.
- [11] LCO Global Sky Partners website. <https://lco.global/education/partners/>.
- [12] OpenScience Observatories (OU) public observing portal. <https://www.telescope.org/>
- [13] IAC press release. High School students in the Canary Islands discover two variable stars. <https://www.iac.es/en/outreach/news/high-school-students-canary-islands-discover-two-variable-stars-0>
- [14] Fitzgerald, M.T., Danaia, L.J. and McKinnon, D.H. (2017). Barriers Inhibiting Inquiry-Based Science Teaching and Potential Solutions: Perceptions of Positively Inclined Early Adopters. *Research in Science Education*. ISSN 1573-1898.

Session

*Complete Papers –
Posters*

III

Session II.I

Primary and Secondary Teacher Education

Night, sky and stars: providing pedagogical material for autonomous teachers

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Abstract

For several years, the team of the educational and outreach office of the Observatoire de la Côte d'Azur (Nice, France) has developed several tools and activities to disseminate knowledge in astronomy. Our pedagogical contents and activities are initially conceived for a school use, to be led in the classroom by scientists and members of our team. However, we have made them available on-line, for a larger use. With this aim, we have developed several sheets defined by the target audience (age and school level) that are available on our Observatory website. Thanks to them, it is now possible for everyone (other outreach professionals, scientists, teachers, parents and so on) to download our contents and carry out our activities in total autonomy. Activity-explanation and communication videos will be soon available.

1. Introduction

Outreach is one of the four missions of the Observatoire de la Côte d'Azur (OCA) and is the core of the work done by the educational office team. Each year, we develop projects with several schools and we carry out many astronomy sessions in the classes. We also host stands during public science events.

The projects developed with the teachers offer a progression in astronomy know-

ledge. Some of them conclude by the participation in a real research project, with a remote observation with a professional telescope that provides data to professional astronomers. This work has allowed us to develop and improve many activities to deal with different topics in astronomy and especially those related to the research work at the OCA. To make public profit from these educational contents, we decided to make them available on-line. We adapted the activities to be used independently and we developed a series of educational sheets intended for a large audience.

2. The educational sheets

2.1 How do they work?

Each activity is explained by:

- a sheet for teachers or any kind of tutors,
- a sheet for pupils or any kind of learners,
- a corrected sheet and annexes if necessary.

Teacher's worksheets contain objectives, links with the curriculum, activity timing and background information (fig.1) whereas pupil's ones contain exercises and construction instructions.

The activities are classified according to student's levels with progressive star-temperature colours: 6-10-year-olds in red, 8-13-year-olds in orange, 12-16-year-olds in yellow, 14-17-year-olds in blue, 16-18-year-olds in purple.

2.2 Which activities?

For the time being, nine activities have been completed and are available in French on our website: <http://www.oca.eu/materiel-pedagogique>

- **White light and coloured light.** (Construction activity for 6-10-year-olds): The white light is a combination of several coloured lights, from purple to red (rainbow colours). How is it possible to decompose white light and observe each colour radiation? Furthermore, how could we recombine colours to make white?
- **Construction of a spectroscope with a CD.** (Construction activity for 8-13-year-olds): This device enables users to disperse light and observe the spectrum of a luminous source.
- **Invisible light.** (Practical activity for 12-16-year-olds): Is visible light the only type of radiation used in astronomy? Is it possible to become invisible?
- **Discover the sky with Stellarium.** (Practical activity for 14-17-year-olds): An activity with Stellarium software that makes everyone understand the sky and want to observe it night and day.
- **Constellation machine.** (Construction activity for 14-17-year-olds): A construction activity to understand that constellations are human-mind compositions and to see the 3D positions of stars in three very-known constellations: Orion, Cassiopeia and the Lion.
- **Sky chart.** (Practical activity for 14-17-year-olds): The most useful device to get your bearings in the night sky!

- **From bulbs to stars.** (Practical activity for 14-17-year-olds): What information can we get from the light provided by stars and nebulae? A parallel with different light bulbs might be helpful to understand it!
- **Solar spectrum.** (Practical activity for 16-18-year-olds): The solar spectrum gives us information to determine the chemical components of our star.

2.3 What kind of activities?

Two main kinds of activities compose our educational sheets. Firstly, construction activities allow students to build a device to understand the physical or astronomical notions implied. These activities need a list of material to ensure the good progress of the audience. Secondly, practical activities consist in a succession of experiments or observations with questions to test student comprehension. These activities always include a corrected sheet.

3. Hyperlinks

To download our activities, get information about all our actions and contact us:

- <https://www.oca.eu>

To discover on the web other contents and activities developed by our team:

- <http://medites.fr/parcours-pedagogiques/observation-univers>

4. Conclusion and Perspectives

We have made available on-line several educational activities about astronomy. They will help us to full our main goal: the dissemination of astronomy knowledge to a large audience. We have also made short videos to promote our activities and to help with their understanding.

The development of new contents is on-going, and for this reason we will be grateful to anyone who shares experiences and gives us a return about our activities led in classroom or any kind of event. (For any return, please contact eduoca@oca.eu).



Fig. 1. Pattern for the first page of a teacher's sheet

How to introduce pre-service teachers to mathematics and science subjects: the use of Human Orrery in teacher training

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Abstract

A training program for pre-service primary teachers was set-up in 2018-2019 with the intention to enhance their knowledge in astronomy and their ability to set-up STEM activities. We introduced them to a specific pedagogical tool, the Human Orrery, which is made to propose a motivating and embodied experience of the Solar System dynamics. All teachers created and implemented a two-hour activity whose

focus was on different mathematics and science topics, within the context of the Solar System. Two of them are described and analysed thoroughly in this paper. It shows on the one hand how trainees succeeded to have different concepts interconnecting through the use of the Human Orrery, and on the other hand the difficulties they encountered in terms of astronomic knowledge and STEM activities' design.

1. Introduction

STEM literacy (Science Technology Engineering Mathematics) is a crucial issue for European educational policies today, as emphasized by successive trans-European studies (Dorrio & Scientix Ambassador, 2019). Declining interest in scientific knowledge usually comes from the misguided view that mathematics and science involve only abstract concepts that are highly complex and distant from everyday cognition and our ordinary world experience. Astronomy attests to the contrary: it provides a motivating context for both boys and girls (Rose et al., 1992) connecting the concrete and the abstract, the mysterious and the familiar. It may also be instrumental in developing essential observational skills, including spatial and multidimensional thinking, which are extendable to other STEM areas. Finally, astronomy can provide crucial insight into the methods of scientific inquiry, the fundamental laws of physics, as well as core mathematical concepts.

We aim to promote an enhanced multimodal teaching environment for mathematics and physics, within the context of the Solar System. A specific training program for preservice primary teachers (PPT) was set-up in order to provide knowledge in mathematics, science and general astronomy to PPT within the context of a Human Orrery. As a consequence, sequences based on the use of Human Orrery were implemented with different classes in primary schools. Their analysis reveals if and how PPT acquired astronomy, science and mathematics knowledge and to what extent they were able to set-up efficient STEM learning.

2. The Human Orrery as a pedagogical tool

An Orrery is a mechanical or digital device designed to illustrate the motion of the planets around the Sun and their changing positions in the sky. On a human Orrery, hereafter called LiOr (Living Orrery) the orbits of planets and comets are drawn at a human scale allowing movements in the Solar System to be enacted by the learners (Asher, Bailey, Christou, & Popescu, 2006; Rollinde & Decamp, 2019). The LiOr integrates people directly into the Solar System experience. As they engage in the walk along planetary orbits, subjects develop an understanding of the motion of the planets in the Solar System through their sensing and moving bodies. Using a STEM approach involves concepts in physics (velocity, forces, reference frames, etc.) and mathematics (measure, proportionality, geometry, etc.) into a tightly coordinated immersive experience.

Researches related to the LiOr in the referenced papers and in this paper are based on the framework of “conceptual change” where students build new ideas in the context of old ones (Vosniadou, 1991; Frappart & Frède, 2016; Viennot & Décamp, 2018). In the specific context of embodied learning with the LiOr, it is assumed that refined knowledge structures emerge from multimodal body-based interactions with the world around us (Varela, Thompson, & Rosch, 1993; Radford, 2014; Johnson-Glenberg & Megowan-Romanowicz, 2017).

The LiOr that we use is printed in a large map of 12m by 12m (see Figure 1). It allows one to follow the orbits of the inner planets (Mercury, Venus, Earth and Mars) and Jupiter; the inner planets are located inside the asteroid belt that is materialized with a grey colour together with the orbit of the largest asteroid known, Ceres. The highly

eccentric orbits of two comets are also used: Encke (the smallest elliptical orbit) and Churyumov-Gerasimenko. This choice of objects illustrates different type of movements while keeping the size of the LiOr reasonable. Earth is at one meter from the Sun (spatial scale), while Jupiter's orbit has a diameter of 10,5m. The orbits of all bodies are materialized by dots at constant intervals of times, with accurate elliptical shapes. Note that orbits are near-circular for the five planets and Ceres.

The interval of time may be different for each orbit, but is always a multiple of 16 terrestrial days: For Earth, there are 23 dots separated by 16 days, which would make a period of 368 days. For Jupiter, there are 54 dots separated by 80 days, which makes a period of 4320 days instead of the real period of 4332,59 days. Note that this difference may be used as an introduction to the Euclidian division in mathematics. A sound (either a clock or hand claps) is heard regularly. The interval of time between two sounds corresponds to 16 terrestrial days (temporal scale). Every user makes one step during this time interval. Then, the person that enacts Earth walks from one point to the next (distance) in one step (duration), while "Jupiter" has to do five steps (five times 16 days) to reach the next point.

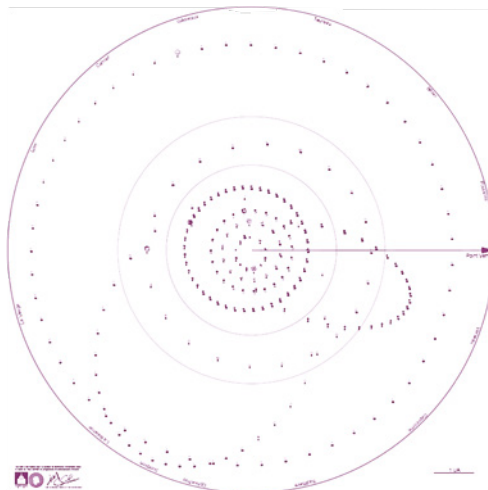


Fig. 1: The 12m by 12m Human Orrery representation of the Solar System, including orbits of Mercury to Jupiter, the asteroid Ceres and two comets, Encke and Churyumov-Gerasimenko.

Through our ongoing work, seven LiOr were built in France (one for a science centre, one in a public place in Paris, five in primary or secondary schools), one was drawn in a Lebanon school and a science centre in Vietnam purchased one map¹⁷. Different sequences have been co-constructed by teachers and researchers with a recent focus on interdisciplinary sequences based on mathematics, geography and science education research (Abboud, Hoppenot, & Rollinde, 2019; Rollinde, 2019).

17 See planetaire.overblog.com (in French) and ldar.website/esmea

Activities with the LiOr provide unique opportunity to create meaningful connections between different academic subjects through the context of astronomy. This has been advocated by in-service primary and secondary teachers during regular training sessions led since 2015:

- “Activities with the LiOr enabled me to show an effective link between mathematics topics and science topics.” “The training I received has contributed to make me more engaged in teaching interdisciplinary themes.”

- “I now know better the difficulties of the pupils in relation to the knowledge at stake when learning some astronomy notions.” “Using the LiOr allows the notion of velocity to make more sense for young learners.” “Several mathematics concepts seem now to make more sense to pupils: radius, perimeter, distance calculation, time calculation.”

3. Astronomy in the French primary school curricula

The astronomy knowledge is included in the curriculum sections “describing the world” and “Planet Earth and its environment”. It includes the description of the shapes of the planets (assumed to be spheres) and their orbits (assumed to be circles). The movement of Earth around itself is observed and used to explain day and night cycle, and the revolution around the Sun is inferred through the seasons and variation of the inclination of the Sun (which may be used to discard the distance as an explanation for seasons).

Strong connections can be made with other subjects not directly linked with astronomy in the curriculum including the appropriation of notions of time (day and night, calendar, clocks and age...) and space (maps, scales), which require measures of length and duration with specific units. The notion of scales is often used to investigate the Solar System model considering both the sizes of planets and the distances between orbits (e.g. Barab, Hay, Barnett, & Keating, 2000; Schneider & Davis, 2007; LoPresto, Murrell, & Kirchner, 2010); the large range of numbers involved in the description of the Solar System being ideal for specific activities on numeration. Geometrical figures, linear and circular trajectories may be described in the context of orbits going from circles to ellipses (involving respectively segments and triangles as will be discussed in one of the proposed sequence below). Finally, the ability to measure different physical quantities together with the recognition of relation between two quantities is initiated in the cycle 3, with a focus on the velocity as a specific case of proportionality. It may then be applied in the context of the movement of planets and comets (Abboud et al., 2019).

4. Preservice primary teachers training program

The training program was set-up in the context of the preservice primary teachers training institute (INSPE) of the University Cergy-Pontoise (Academy of Versailles). Note that in France, a specificity of PPT is their polyvalence (teaching all subjects to their class). This may be better valorized during a STEM training program based on astronomy in general and specifically on the LiOr.

The program ran during the academic year 2018-2019, for a total of five 3-hours sessions and a one-day session for implementation in two primary schools and for post-analysis.

Session 1. PPT discovered the LiOr throughout a preliminary set of activities developed by the educators. The focus was on the enactment process.

Sessions 2/3. A science course followed by a mathematics course tackling the main physics, mathematics and astronomy concepts that are/could be engaged when using the LiOr and the related goals that are present in the curricula as described above. Training activities in these two sessions were grounded in theoretical frames from mathematics and science education.

Sessions 4/5. In groups of 4-6, PPT design one pedagogical setting using the LiOr for one primary class each. Each setting includes two phases using LiOr in the courtyard and a printed version of the LiOr in the classroom, connecting thus different levels of space. Once the learning goal is chosen, preparation materials are conceived along with observation grid in order to allow the after-implementation analysis.

4.1 First session: enacted astronomy

During the first session, PPT discovered the LiOr using a permanent version of it located in a public garden in Paris. Most had a near to zero knowledge on astronomy, or at most knew the names of the different objects in the Solar System.

They acted first as learners following activities usually made with classes by the educators (see details in Rollinde et al., 2020; Rollinde & Decamp, 2019): (i) Name the objects on the LiOr – inner, telluric planets versus gaseous planets; many of them tried to find the Moon; asteroids, comets – and make connections with other known objects such as meteorites, shooting stars. (ii) Observe the shapes of the orbits are not perfect circles using a rope. (iii) Walk along the different orbits to learn about the different speed of the planets and the varying speed of the comet.

We then had a more specific discussion about embodied learning and the connections that can be made between knowledge and perception: enactment of distance with the visual observation of dots on the floor, duration with the audible observation of the sound of the claps and velocity with the visual or kinesthetic observation of their own displacement. The educator emphasized the different roles of actors and observers during a setting using the LiOr.

The activities designed and implemented by PPT were intended for primary schools' pupils aged 7-9 years.

4.2 Implementation of settings in a half-day session

The one-day session was split in two half-days. In the morning, PPT went to two primary schools that participate to another project involving the LiOr (Figure 2). The different classes had learned with their teacher basic facts about the Solar System and were aware of the specific design of the LiOr (Section 2) before the session led by the PPT. Note that PPT did not meet with the children before. Each group managed successively two classes during two hours (two phases of one setting).

In the afternoon, a last reflective training session took place based on observations and experiences' feedback. The aim is to confront the a-priori analysis with the actual implementation in class. Giving the experimental dimension of the class-setting, the focus of the analysis was more on the conception and realization of the sequence from the point of view of the didactical content rather than on the teachers' gestures or the effective learning of the children.

5. Analysis of two settings using the Human Orrery

We present here two of the four settings that were designed and implemented by PPT. For each, we first describe the goal of the setting, the knowledge at stake as foreseen by the PPT. Then, the effective course of the experience is given with individual and collective phases, including difficulties encountered by the PPT as well as interest of the activities in terms of learning.



Fig. 2: The Human Orrery set up in the courtyard of one of the French primary school where activities took place

5.1 The speed of the planets

This setting aims at the comparison of planets' speed through measure of lengths travelled in a given unique duration on the one hand, on the other through participants' own movement. This goal requires the understanding of the notions of distance and duration as well as their measure. To be precise, the relation between travelled distance and velocity may be called upon for a constant duration only.

The first phase of the setting occurred in the classroom, and focused on the measure of lengths. The second phase occurred in the courtyard and focused on the observation of one planet that pass another one, which may be connected to speed.



Fig. 3: Measure of the length of one portion of the orbit using the rope.

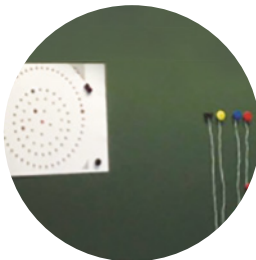


Fig. 4: Comparison of the length of the measured with a ruler in order to quantify the distance and to write this number on the sheet for each planet.



Fig. 5: Pupils walk on a smaller version of the Human Orrery.

Phase 1: in the classroom, measure of lengths

The session in the classroom started with a brainstorming about pupils' knowledge of the Solar System through the description of the picture of the LiOr (Figure 1). The PPT in charge of this setting reinforced the idea that planets are only represented on the drawing. Yet, there was a confusion in their wording between continuous trajectories (orbits) and discrete positions (points along the orbit separated by a constant time lapse).

The PPT then described "the measure of trajectories" as the goal of the activity; confusing the trajectory with its length (ignoring for example its shape). A discussion was engaged with the class about the best method to measure a length on a curved line. This allowed the introduction of the rope as a measuring tool. The method was then illustrated by the PPT with one orbit.

The class was divided into 4 groups of 3-4 pupils with one planet assigned to each (from Mercury to Mars). The task was to measure the trajectory of the planet while moving over 12 points on its orbit, by drawing one stick of the rope for each point (Figure 3). Pupils, often helped by PPT, were successful.

Ropes were collected by PPT and placed one next to the other on the blackboard, in increasing order but without mentioning or writing the name of the associated planet (Figure 4). PPT then had the pupils established that the longest rope is related to the largest displacement. They concluded that trajectories are indeed different but without connection with speed. A sheet was distributed to the pupils with a summary of the procedure (description of points on the drawing, measure of distance over 12 points with a rope). The lengths of the ropes were then measured with a ruler in order to quantify the distance and to write this number on the sheet for each planet.

The conclusion, already written, stated that "all planets do not travel the same distance during the same time interval." This was the first and unique mention of a constant time interval. The next sentence related travelled distance and speed without mention of duration: "The longer is the rope, the larger is the planet's travelled distance. It is thus faster." The PPT concluded by notifying that the planet with the longest rope is "thus" the fastest one (Mercury).

Phase 2: in the courtyard, embodied and observed planets' overtaking

For this setting, a small version of the LiOr was used with the orbits of inner planets (Mercury to Mars) and one comet (Encke). Different groups of 4 pupils moved on the map and learned how to walk while following a rhythm. The others were observers (Figure 5) and had to check if the rhythm was respected and if walkers follow the points along their orbit. This was successful and pupils had no specific difficulties to walk and to observe. The PPT that clapped the rhythm entertained herself several

times by accelerating the rhythm after a little while. This hints towards a clear misunderstanding of the crucial idea of constant interval time.

Next observations were directed towards moments when one planet pass another one. Such moments were clearly noticed. Yet, no connection was made between overtaking and planets' speed. Hence, no connections between the two phases of the setting.

Knowledge of the PPT: synthesis

Different notions were confused in the PPT discourse: on the one hand, continuous trajectories and discrete points along it; on the other, the relation between distance, speed and duration is not considered as a relation between three variables. Duration is rarely, or never, mentioned by PPT. This makes difficult the understanding of speed that is confused with travelled distance during the activity of measure. If a connection had been proposed in the courtyard with this activity, pupils would have noticed that the planet that travelled the shortest distance (Mercury) was the fastest one. Of course this is explained by Mercury's shortest period of revolution... Yet, in the actual setting, those notions were not discussed in the courtyard where the focus was solely on overtaking events. Note that overtaking may be linked to the instantaneous speed of the planets (Rollinde, 2019).

5.2 The shape of the orbit

The goal of this setting was to discover a new geometrical figure, the ellipse and procedure to draw one, in connection with the known properties of a circle. This is a difficult goal that requires different knowledge that primary pupils have not yet acquired at this age.

The first phase occurred in the courtyard with the discovery of Solar System's objects and the shape of their orbits, followed by the activity of tracking the points along the elliptical orbit of the comet with a rope. The second phase in the classroom was intended to reproduce this construction for the orbit of Saturn, on a A3 format paper.

Phase 1: in the courtyard, discovery of an ellipse

Pupils were first left to move freely on the LiOr, taking advantage of the unusual size of this object (12m by 12m) as well as the unusual place of learning outside the classroom, to enhance their motivation (Figure 6). Pupil did make various observations and discussed them. Sun was spotted rapidly at the centre of the map. The symbol used for comets (a circle and different small lines in one direction) is similar, yet different, to the usual drawings of the Sun, questioning the possible existence of other Suns. Some of them recognised Jupiter in the picture used for Venus. Spontaneous debates among them solved those issues (only one Sun; planets correctly named and ordered in the Solar System). The Moon was searched by all pupils. Some spot the images of Mercury or the asteroid Ceres that are similar to the Moon. None could be sure about where the Moon was, but all were willing to spot it. Many pupils noticed the points and associated numbers, connecting those with the orbits of the different objects. Hence, the orbit of Ceres was described by one pupil as the movement of the Moon.

Then, pupils sat altogether near the LiOr and explained their discoveries one after the other. All planets are then named and some orbits are shown. The case of the Moon was discussed together with artificial and natural satellites. PPT explained that the Moon is so close to Earth that its own trajectory is located behind the different points along the orbit of Earth. We remind that the size of the objects cannot be scaled on the LiOr. Thus the size of the Moon does not explain why it cannot be seen. This detail was not mentioned by PPT.



Fig. 6: Free discovery of the Human Orrery.



Fig. 7: Pupils walk along the different trajectories on the Human Orrery.



Fig. 8: Pupils are located on each point along Encke's orbit.



Fig. 9: The straight rope describe all the points of the orbit.



Fig. 10: Tracé de l'orbite de Saturne.

Once all elements were described, pupils were set to walk along each orbit. They had to walk along the trajectories from one point to the next, without taking care of their speed or rhythm (Figure 7). Next group discussion revealed that some orbits are not circles but ovals. The PPT took the opportunity of comparing circular and elliptical orbits, and asking how one may draw a circle. As pupils proposed a geometry compass, the notion of centre emerged. The PPT build on it the notion of focus for an ellipse. She then proposed to compare all orbits. Yet, the next activity will focus solely on Encke.

Pupils are set along Encke's orbit (Figure 8). One pupil repeated the need for two centres, and corrected her words into two focus after PPT's intervention. One PPT stood at the position of the Sun and explained that the Sun is always one of the two focus. A second PPT stood at the approximate position of the second focus, "we know the second focus is about here". The two hold a rope that join on two straight lines the Sun and one point along the orbit, and the same point and the second focus (according to the gardener method). They ask the pupils to check if the same rope, with the same length, may go through all the points along the orbit while those two segments are kept straight (Figure 9). The PPT conclude that "we have been able to track the planet" (confounding the planet and its orbit). Yet, pupils could not report the different steps of the procedure when asked to do so. The goal of the activity was not clearly identified beforehand. Specifically, pupils cannot identify the positions of the two PPT with the focus, a notion they were not aware before. PPT explicated again all steps that were required for the next phase.

Phase 2: in the classroom, construction of Saturn's orbit

After a brief record of what has been done in the courtyard, pupils were asked to name the nearest planet that is not shown on the LiOr: Saturn. The goal was then set to draw its orbit on top of the map of the LiOr. We note that this goal did not emerge naturally from the class, and that it was not clearly connected to the orbit of Encke which was the focus of the activity outside. One of the PPT explained how to proceed using the drawing of the LiOr pasted on the blackboard. Only one end of the rope was hold at the Sun's position, assimilating then the orbit to a circle. Another PPT noticed that the orbit was elliptical and that a second focus was required. The position of the second focus was indicated to be at the position number 5 along Earth's orbit, without further explanation. We note that this position is quite close to the Sun compared to the distance from Sun to Saturn, since Saturn's orbit is not far from a circle. Thus, the design of the construction for Saturn will be quite different compared to Encke.

Pupils divided into groups had one rope with the correct size at their disposal. They first had to cut the outer circle of the LiOr, paste it into a A3 format paper, and then draw the ellipse (Figure 10). Some pupils could not find the Sun, neither the focus of the ellipse. Those pieces of information were given in the courtyard on the large map, but the connection between two spaces of different size was not correctly build in the design of the activity. The actual drawing was difficult and PPT had often to guide each group. A difficulty arose as the rope crossed the major axis of the ellipse. The rope had to be turned over, creating in all drawings a discontinuity. Moreover, some groups had not pasted the circle at the centre of the page. The orbit of Saturn went out of the page (both difficulties are visible in Figure 10 that was one of the best realization).

The actual drawing took a long time, and the activity ended without a clear institutionalisation of the method, not a pooling of all drawings.

Knowledge of the PPT: synthesis

This setting allows to tackle a difficult concept, for the pupils as well as for the te-

achers. Its focus is thus more on an instrumented activity of construction without some reflection on the mathematical interpretation of the rope and of the point representing the focus. Although the link with the circle was mentioned early, by connecting in PPT's discourse the notions of focus and center, pupils did not experiment this connection. This may have been done by moving further and further away the two focus, shifting then continuously from the circle to the ellipse. Besides, the rope should be connected to mathematical concepts known by pupils. In other words, as one draws a circle, half of the straight rope stands for the radius, segment of constant length that connects the center and each point along the circle; while for the ellipse, the straight ropes embodies a triangle (connecting three points) whose perimeter is constant. We note that this last notion may be out of scope for primary pupils, and possibly also for PPT! Those difficulties explain why activities in this setting had to be proposed by the PPT and cannot be initiated by the pupils themselves. PPT skipped abruptly from the observation of shapes to the drawing procedure, tasks that have not the same knowledge issues. Moreover, from the first to the second phase, the observed or drawn orbits were not similar. The connection between the two spaces (of different size) was no more foreseen, increasing thus the pupils' confusion.

6. Conclusion

Mathematics knowledge in primary school must be related to real-life situations or objects. Similarly, connections between abstract concepts and perceptions is among the objectives of the curricula through physical activities. In general, everyday situations are usually preferred by teachers. Yet, astronomy provides motivating and real situations that are not centered on our geocentric situation. In particular, the LiOr enhances such connections with human bodies made to physically and symbolically "stand for" something else than themselves – namely celestial bodies; and the physical space surrounding users (proximal) made to symbolically stand for outer space (distal), while functioning as an immersive teaching-learning-and-reasoning space.

The training program described in this paper was intended to promote a STEM approach and to improve the astronomy knowledge of PPT. We showed through the two settings described here that they were indeed able to link the context of the Solar System with generic mathematical and scientific notions. The connection between distal objects was made in two different spaces using physical users' bodies on the LiOr and measuring tools on the printed version in the classroom. These different approaches of the same concept are promising.

Nevertheless, we highlighted several difficulties due mainly to a lack of time devoted to activities' design which could had allowed the PPT to better appropriate the scientific notions at stake and predict the difficulties that pupils could encounter. A more efficient training, in terms of astronomy knowledge and pedagogical setting, requires more time to complete the a-priori analysis, test the activities before going to the real class, and have a reflection time later on after the implementation. Besides, such STEM activities are better set up within a global long-term project with one's own class.

Those conditions are on the edge to be set up in different contexts: a new PPT training program in 2019-2020; long-term projects with secondary schools following a three-year series of lifelong training programs; and a long-term project with the in-service teachers in the same primary school that was engaged in the activities presented in this paper.

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References

- Abboud, M., Hoppenot, P., & Rollinde, E. (2019). *Enhancing mathematics and science learning through the use of a Human Orrery*. CERME11, Utrecht, Netherlands. <https://hal.archivesouvertes.fr/hal-02303967>
- Asher, D. J., Bailey, M. E., Christou, A. A., & Popescu, M. D. (2006). The Human Orrery: A New Educational Tool for Astronomy. *Astronomy Education Review*, 5(2), 159-176. <https://doi.org/10.3847/AER2006024>
- Barab, S. A., Hay, K. E., Barnett, M., & Keating, T. (2000). Virtual Solar System project: Building understanding through model building. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, p. 719.
- Dorrio, B. V., & Scientix Ambassador. (2019). Scientix, the Community for Science Education in Europe. *Hands-On Science*, p. 110.
- Frappart, S., & Frède, V. (2016). Conceptual change about outer space: how does informal training combined with formal teaching affect seventh graders' understanding of gravitation? *European Journal of Psychology of Education*, 31(4), 515-535. <https://doi.org/10.1007/s10212-015-02754>
- Johnson-Glenberg, M. C., & Megowan-Romanowicz, C. (2017). Embodied science and mixed reality: How gesture and motion capture affect physics education. *Cognitive Research: Principles and Implications*, 2(1), 24. <https://doi.org/10.1186/s41235-017-0060-9>
- LoPresto, M., Murrell, S. R., & Kirchner, B. (2010). Assessment of a Solar System Walk. *The Physics Teacher*, p. 236.
- Radford, L. (2014). Towards an embodied, cultural, and material conception of mathematics cognition. *ZDM*, 46(3), 349-361. <https://doi.org/10.1007/s11858-014-0591-1>
- Rollinde, E. (2017). Learning Science Through Enacted Astronomy. *International Journal of Science and Mathematics Education*, 17(2), 237-252. <https://doi.org/10.1007/s10763-017-9865-8>
- Rollinde, E. (2019). Enacting Planets to Understand Occultation Phenomena. *JOE – Journal of Occultation and Eclipse*. <https://hal.archives-ouvertes.fr/hal-02303664>
- Rollinde, E., Couanon, L., & Ballenghien, S. (2020). Incarner la notion de vitesse en classe de 6e. *Le Bulletin de l'Union des Professeurs de Physique et de Chimie*. <https://hal.archivesouvertes.fr/hal-02309246>
- Rollinde, E., & Decamp, N. (2019). Enacting planets to learn physics. *Journal of Physics: Conference Series*, 1287, 012011. <https://doi.org/10.1088/1742-6596/1287/1/012011>
- Rose, G., Schlegel, K., Rinnert, K., Kohl, H., Nielsen, E., Dehmel, G., ... Steinweg, A. (1992). The ROSE project. Scientific objectives and discussion of first results. *Journal of Atmospheric and Terrestrial Physics*, 54(6), 657-667. [https://doi.org/10.1016/0021-9169\(92\)90104-S](https://doi.org/10.1016/0021-9169(92)90104-S)
- Schneider, S., & Davis, K. S. (2007). *The Dimensions of the Solar System*. *Science Scope*, p. 16.
- Varela, F. J., Thompson, E., & Rosch, E. (1993). *The Embodied Mind: Cognitive Science and Human Experience* (2017e éd.). MIT Press.
- Viennot, L., & Décamp, N. (2018). Concept and critique: Two intertwined routes for intellectual development in science. In *Complementary and Converging Perspectives on Conceptual Change*, T. Amin and O. Levrini, New York: Routledge, 190-197. <https://hal.archivesouvertes.fr/hal-01738940>
- Vosniadou, S. (1991). Conceptual development in astronomy. In *The psychology of learning Science* (Glynn, Yeany, Britton, p. 149-177). Routledge.

Strategies for Implementing an Online Professional Development Experience: AWB's Building on the Eclipse Program

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Abstract

Astronomers Without Borders “Building on the Eclipse Education Program” explored how to impact science identity, attitudes towards STEM and inspire audiences to explore careers in STEM. Inspired by a total solar eclipse, educators and scientists were brought together in a sustained online community of practice to support one another in learning about the Sun and light after audiences were inspired by the 2017 Solar Eclipse. The program was rebooted in Spring 2018 and continued to collect and analyze data in an attempt to collect information on audiences for the next US total solar eclipse in 2024. Several best practice strategies were used in the design of the program. This poster will explore the design of the program, the successes and challenges during implementation and evaluation, and our future plans for the effort.

1. Introduction to the Building on the Eclipse Education Program — Background and Description

In anticipation of the Total Solar Eclipse in August of 2017, Astronomers Without Borders (AWB) received funding from Google to prepare educators for the eclipse and to continue learning from light afterward. A program logic model with inputs, outputs and outcomes was developed based on the extensive experience of partner organizations and needs assessment information for informal and formal educators from NASA^{18,19}.

AWB and its partners were part of a huge nationwide effort by many institutions to inform and excite the public leading up to the eclipse. This spectacular event was

18 <http://smdepo.org/post/7213>

19 <http://smdepo.org/post/6292>

expected to inspire the teaching and studying of STEM fields. Support for schools based on that inspiration after the eclipse was lacking, however. AWB's program supported educational institutions of all kinds to continue teaching STEM topics based on the inspiration of one of nature's most spectacular events. Schools in under-served communities were the focus of recruitment but all were welcomed.

Preparation for the eclipse was supported using existing resources including online lesson plans and professional development webinars that were curated and searchable. Eclipse glasses were provided at cost, where needed, with support for institutions lacking funding to purchase them.

The post-eclipse program was based on sunlight to connect the eclipse experience with broader STEM topics (not just astronomy) of interest to schools, clubs, and nature centers nationwide using quality resources supporting Next Generation Science Standards (NGSS) and other educational standards. Activities were based on a spectroscope kit developed by the Stanford Solar Center under a NASA grant for the SDO mission outreach office (hundreds were available free thanks to the manufacturer, Rainbow Symphony). A database of over 140 activities could be filtered by institution type, topic, standard, and grade band. Professional development was provided in live virtual sessions, all of which were archived for later viewing. Three suggested culminating projects and events (for elementary, middle, and high school) were provided. Results could be shared with other classes through online presentations. An online community of practice on Trelliscience.com (created by the American Association for the Advancement of Science (AAAS)) was the home for the activities database, professional development resources, discussions, events, and announcements.

Designed to prepare students for NGSS performance expectations, the sequence of activities was flexible to accommodate multiple schedules, group formats and previous learning. Final challenges were designed to motivate the activity sequence. Each included an NGSS performance expectation, an image as the anchor phenomenon, a statement on the challenge, and a question to pose to students.

1.1 Best Practice Strategies

According to *Effective Teacher Professional Development* by Linda Darling-Hammond, Maria E. Hyler, and Madelyn Gardner (2017), with assistance from Danny Espinoza²⁰, there are seven widely shared features of effective professional development. All of these features, listed below, were incorporated into the design of the Professional Development Program:

- **Is content focused:** Astronomy content was the inspiration to participate (given the upcoming total solar eclipse) and was directly related to classroom content. Effective pedagogical techniques included: awareness of and addressing “facets of learning” (a.k.a. Mis/Pre-Conceptions), and using models. The program was also designed for NGSS, aligning it with the state/district priorities for many US locales.
- **Incorporates active learning:** Since participation was voluntary, the content and activities were clearly of interest to those who registered. Despite the online format, many active learning opportunities were provided. Video cameras and eyes can be used to explore ways in which light of different energies (wavelengths) interacts with detectors, spectroscopes and human eyes. Participants could try activities and then return to the platform for advice, to address challenges in the classroom, or to clarify connections to science concepts.
- **Supports collaboration:** Our online platform strongly encouraged collaboration between educators of various levels and between disciplines including

20 https://learningpolicyinstitute.org/sites/default/files/product-files/Effective_Teacher_Professional_Development_REPORT.pdf

supports for English Language Learners. Suggestions for involvement of whole schools were made, particularly with regard to the event of the total solar eclipse, while encouraging cross-curricular connections.

- **Uses models of effective practice:** Introductory videos and synchronous videoconference sessions were used to model effective practice. A curated collection of lessons utilizing these strategies was also created.
- **Provides coaching and expert support:** Master educators and amateur astronomers were invited into the online community to offer support and coaching as needed.
- **Offers feedback and reflection:** The online platform, and prompts from instructors, allowed for reflection on learning and implementation. The closed online workspace allowed participants to admit to a need for assistance that they might not reveal on an open forum.
- **Is of sustained duration:** The online community was open and active for one and a half years and would have remained open longer if the online platform (Trellis by AAAS) hadn't been terminated. Since the program was offered during a specific semester, participation was expected primarily during that time but there was nothing (including cost) that prevented repeated participation or a return to the online community whenever support was needed.

1.2 Program Design

The program designers incorporated these effective practices into our program design. We designed our own logic model to describe our theory of change by organizing our resources, inputs, activities, outputs and short and medium outcomes. In addition, AWB created a pre-post survey strategy to measure the effectiveness of our program.

2. Results

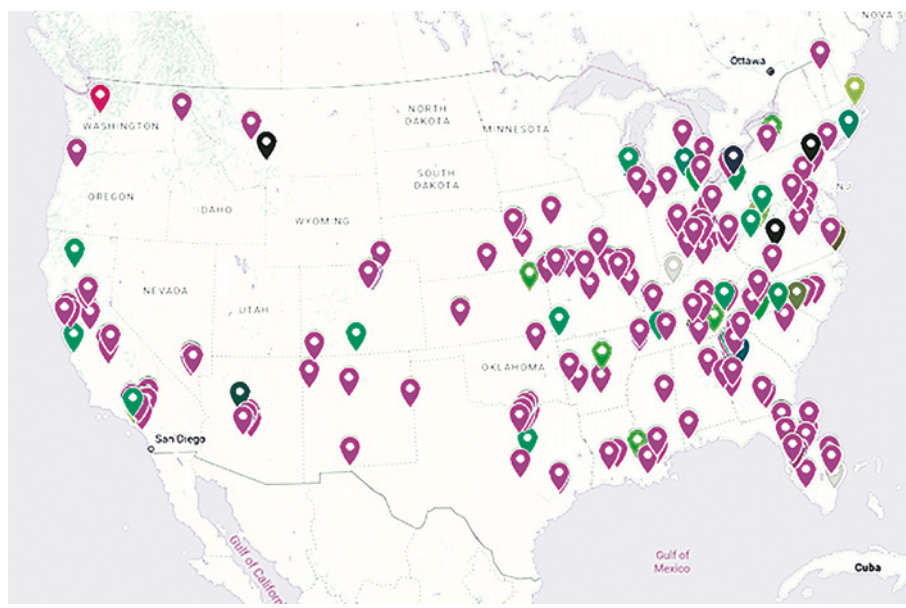
2.1 Participation

Two hundred twenty registrations were completed in 2017, and 29 in 2018. Pre-program survey information was collected at the time of registration. The majority of registrants were formal teachers. There was a high proportion of underserved schools represented in the program as measured by the percentage of students on free or reduced-price lunch programs. In 2017, the median percentage of students enrolled in free and reduced lunch was 70%, and one quarter of the schools had 90% or more in these programs. In 2018, the median percentage of students enrolled in free and reduced lunch was 83%, and more than one quarter of the schools have 100% in these programs.

Registrants estimated the range of their likely audience as follows:

| | Minimum | Maximum |
|------|---------|---------|
| 2017 | 42,212 | 55,320 |
| 2018 | 5,402 | 7,810 |

Fig. 1: Estimated Audience Participation by Educator Registrants



| | | | | | |
|--|-------------------------|--|---|--|---------------------------------|
| | Teacher | | Activity Coordinator adult activity center | | K-S Science Resource teacher |
| | School administrator | | Afterschool Provider | | Literacy Coach |
| | Librarian | | Disability Coordinator | | Outreach Coordinator |
| | Amateur Astronomer | | District science administrator | | PTO President |
| | Museum Professional | | Girl Scout stall providing large events for girls | | STEM camp director |
| | Planetarium Staff | | Group Tutor | | Substitute Science Teacher |
| | Scout Leader | | Homeschooler | | Other/ No data |

Fig. 2: Geographic Distribution of Educator Registrants

2.2 Survey Results

In 2017 and 2018, we collected pre-program survey information from the completed registrations. Below are some key results:

| 2017 | 2018 | Educator responses |
|-------|------|--|
| N=220 | N=29 | |
| 83% | N/A | reported that schools in their service area would be in session during the eclipse. |
| 38% | 39% | asked for support materials to create a peer-to peer fundraising program. |
| 85% | 82% | asked for information to receive free spectrosopes. |
| 68% | 61% | are required or preferred to use materials that support NGSS. |
| 99% | 68% | were new to participating in AWB programs. |
| 85% | 86% | were interested in lessons about the eclipse AND studying the Sun after the eclipse. |
| 47% | 32% | expected their audience to view total solar eclipse locally. |
| 46% | 50% | expected their audience to view a partial eclipse locally. |
| 4% | 0% | expected their audience to travel to view total solar eclipse. |

Educators were asked to respond to questions about the attitudes of their participants towards STEM. Below are the medians of responses on a scale of 1 to 5 where 1 is strongly disagree and 5 is strongly agree:

| According to educators their students... | 2017 Pre N=220 | 2018 Pre N=29 | 2018 Post N=5 |
|--|-------------------|------------------|------------------|
| express that they LIKE doing STEAM activities | 5 | 5 | 5 |
| express that they ARE ABLE to do STEAM activities | 4 | 4 | 5 |
| express that doing STEAM activities is IMPORTANT | 4 | 4 | 5 |
| will be inspired to engage in learning more STEAM after watching the eclipse | 5 | 5 | 5 |

Educators were also asked to respond to questions about their own attitudes towards STEAM. Below are the medians of responses on a scale of 1 to 5 where 1 is strongly disagree and 5 is strongly agree:

| Educator responses | 2017 Pre N=220 | 2018 Pre N=29 | 2018 Post N=5 |
|---|---------------------------|--------------------------|--------------------------|
| I like to do STEM activities. | 5 | 5 | 5 |
| I feel capable of doing STEM activities. | 5 | 5 | 5 |
| Doing STEM activities is important to me. | 5 | 5 | 5 |
| I feel knowledgeable about the solar eclipse, solar science and spectroscopy. | 4 | 4 | 5 |
| I feel confident teaching about the solar eclipse, solar science and spectroscopy. | 4 | 4 | 5 |
| I have access to quality activities to help me teach about the solar eclipse, solar science and spectroscopy. | 3 | 4 | 5 |
| I have access to tools that help me to teach about the solar eclipse, solar science and spectroscopy. | 3 | 4 | 5 |

3. Discussion and Conclusion

Information from our Pre-Program surveys showed that educators were highly interested in free materials to support eclipse viewing/teaching. Two-thirds of them needed materials which supported Next Generation Science Standards. Almost all of them were new to AWB the first year and a large percentage of the second year participants were repeat customers which indicates the value they saw in the program. Educators weren't as interested in launching their own fundraising efforts for materials even with our help. We hope that the other information serves to prepare our organization and others in the US for the next eclipse in 2024 which is likely to be even more popular. Pre-Post Likert-scale questions show some growth over time, if there was room to grow in the first place. Especially notable is that the program seems to have increased participants' access to quality activities and tools for teaching as well as increasing their confidence.

While the start to the program was strong in 2017, there were challenges post-eclipse including: getting registered participants into the online community, scheduling professional development sessions when many members could attend, and holding their attention once school began after the eclipse. Collecting post-program data proved extremely difficult and the number of post-program survey responses is too small to report for 2017. It's worth noting that matched results for the post survey show that educators slightly under-estimated their participant numbers, but this may not be a representative sample.

3.1 Future Program Possibilities

AWB is now beginning the process of developing a community of practice for its members, educator participants and international participants in general. We hope that the culminating projects, classroom connection discussions, library of lessons and professional development opportunities and ongoing support developed in this program will become available to educators world-wide. We anticipate seeking fun-

ding to support programs in connection with future total solar eclipses where possible, although this content remains prominent in many educational standards no matter the availability of direct observational events.

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References

- Informal Education Working Group National Survey of Educators – Results. (2014, August 18). Retrieved from <http://smdepo.org/post/7213>
- K-12 Survey on Teacher Professional Development. (2013, October 9). Retrieved from <http://smdepo.org/post/6292>
- Darling-Hammond, L., Hyster, M., Gardner, M., *Effective Teacher Professional Development*, (2017, June) Retrieved from https://learningpolicyinstitute.org/sites/default/files/product-files/Effective_Teacher_Professional_Development_REPORT.pdf

CLEA, a French pro-am initiative to foster astronomy education

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Abstract

The Teachers – Astronomers Liaison Committee (Comité de Liaison Enseignants – Astronomes, CLEA) is a French non-profit and non-governmental association that fosters astronomy education mainly through training sessions in various regions of France, a yearly summer school, and the publication of a quarterly magazine; all those mainly targeting primary and secondary teachers. The association brings together primary and secondary teachers, educators and professional astronomers. We present the organisation of the association, review the actions that CLEA has carried out for more than 40 years and the didactic methods that we promote.

1. Genesis and objectives of CLEA

The Teachers – Astronomers Liaison Committee (Comité de Liaison Enseignants – Astronomes, CLEA) was founded in 1976 following a meeting gathering teachers and professional astronomers. That year, commission 46 “Teaching of astronomy” had invited teachers to attend the XVIth General Assembly in Grenoble, France. Although basic knowledge of astronomy have been taught in France, there have never been proper courses in astronomy in French curricula. Yet, some teachers – most of them being amateur astronomers – have had some good experience to share through CLEA (Gouguenheim, 1993).

Nowadays, CLEA is composed of about 500 members, mostly teachers and professional astronomers, and educators acting in science centres and planetariums.

The main objectives of CLEA have always been to promote the teaching of astro-

nomy in primary (which includes kindergarten in France) and secondary schools, teaching astronomy as such but also astronomy as a culture, as a conveyor of a more general scientific literacy and of the scientific method. We are also convinced that tackling astronomy is a great way of bringing together teachers of various disciplines and thus favouring transdisciplinary approaches. CLEA also contributes greatly to the training of in-service teachers (Gouguenheim, 1993; 2003).

2. Didactical approaches

CLEA encourages a teaching based on experiments and practice (learning by doing). To this end, hands-on activities and models are designed, built and made available. CLEA also pioneered and have been promoting kinaesthetic learning in astronomy (Moon phases or human orrery for instance).

We are also convinced that history of science is an important way of understanding today's astronomy and that it may help teachers to face and deal with the propagation of fake news (flat Earth, Man on the Moon, etc.). Each time possible and relevant, CLEA emphasizes the origin of such or such concept and explains how the evolution of ideas and the accumulation of observations and experiments over decades and centuries yields an evolving knowledge.

3. Training sessions and summer schools

At the national level, CLEA has a recognized expertise in teaching astronomy. On request from local academic authorities, CLEA organises or co-organises 1-to-3-day-long training sessions across the country. Those sessions typically gather between 15 and 20 teachers and the time is shared between seminars given by professional astronomers and hands-on activities. The material and activities developed by CLEA is then exploited (Bottinelli et al., 1990).

Each year, CLEA organises a 1-week summer school in the French Alps. About 40 teachers come together to learn, share, and interact. The format is comparable to that of the shorter training sessions: professional astronomers give lectures in the morning and teachers and/or astronomers propose practical activities in the afternoon (Fig. 2). After sunset, CLEA's and participants' telescopes are set up and a part of the night is spent observing and running activities such as spectroscopy, photometry, etc. One day during the week is devoted to a visit of some site having a scientific interest (IRAM radio observatory, ITER and Cadarache nuclear power research centre, Sun museum, a tour of the sundials in the surrounding villages, etc.) During the summer school, all participants live and share meals at the same place. This aims at installing an atmosphere and a proximity among everyone, to favour exchanges and discussions. Feedbacks from participants are very positive and encouraging.

4. Publications

Four times a year, at solstices and equinoxes, CLEA releases an issue of its quarterly publication, the Cahiers Clairaut, named after the French mathematician Alexis Claude Clairaut (1713-1765). Each issue contains articles written by astronomers and teachers: articles dealing with astronomy/astrophysics or history of astronomy, or with descriptions of projects and practical activities carried out in classes with students or pupils, etc. About half of each issue is devoted to a specific theme. Fig. 3 shows the cover page of the Fall 2019 issue whose theme was "astronomy at kindergarten".



Fig. 1: Morning lecture during the 2019 summer school.



Fig. 2: On-going hands-on activity during the 2019 summer school.



Fig. 3: Front cover of the September 2019 issue of Cahiers Clairaut whose theme is "astronomy at kindergarten".

CLEA also publishes on-line resources, which are, at times, forwarded to schools and teachers by local or national academic authorities.

Every other year approximately, CLEA publishes a book on some specific topics: *Astronomy and Mathematics*, *Constellations*, *Astronomy at school*, *The Sun*, are the latest (Fig. 4). They are also written by professional astronomers and teachers.

5. Concluding remarks and perspectives

CLEA is relatively well known among the French teachers and astronomers, although we still aim at gaining always more popularity. CLEA's expertise in the field of astronomy education and the quality of our educational material are widely acknowledged, and the association plays in role in bridging the gap between astronomers and teachers (Josselin, 2009).

After years of financial support from the Minister of education (participants to our summer schools used to be entirely funded for instance), national budget cuts have affected our activities. CLEA now relies exclusively on the membership fees, the subscriptions to Cahiers Clairaut and sales of books and equipment (models, filters, etc.) to support the organization of training sessions, still with volunteering supervisors.

To remedy the lack of training in astronomy of the pre – and in-service teachers, CLEA aims at being more present and visible in education institutes (INSPÉ) that train pre-service teachers. In addition, it aims at forming local networks of teachers and astronomers that could work together and share ideas.

Eventually, CLEA has a role to play in the revival of astronomy education research (AER) in France (Pitout et al., 2020) and some involvement in European or more international initiatives and networks is considered.



Fig. 4: The latest books on “Astronomy at school” (top) and “The Sun” (bottom)

Acknowledgment

- As it is difficult to cite or consider as co-authors all the people involved, the authors would like to thank all the members who contribute to the success of CLEA. Information, resources and pedagogical materials created by CLEA are available at <https://clea-astro.eu>

References

- Bottinelli, L., Dupré, J., Gerbaldi, M., & Gouguenheim, L. (1990). An Example of Clea Activities in the Training of School Teachers. *International Astronomical Union Colloquium*, 105, 294-296. doi:10.1017/S0252921100086954
- Gouguenheim, L. (2003). Enseigner l’astronomie : l’expérience de 25 ans d’activités du comité de liaison enseignants astronomes CLEA, *ASTER 36 L’enseignement de l’astronomie*, INRP.
- Gouguenheim, L. (1993) Le CLEA et l’enseignement de l’astronomie, *Cahiers Clairaut*, 63, p. 2-5
- Josselin, E. (2009). Comité de Liaison Enseignants Astronomes, bridging the gap between French astronomers and teachers. *Proceedings of the International Astronomical Union*, 5(S260), E26. doi:10.1017/S1743921311003462
- Pitout, F., P.S. Bretones, E. Rollinde, V. Frède (2020) *Astronomy education research in France: survey and analysis*. Preliminary results, this issue.

Session II.II

Astronomy Education Standards, Curriculum and Instruction

Astronomy a solution for the interdisciplinary and transdisciplinary approach in romanian educational programs

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Abstract

The Romanian National Curriculum is in difficulty when it comes to implementing an interdisciplinary and transdisciplinary approach especially for middle school and high school students. Although very popular, astronomy is not currently a discipline of study in the Romanian National Curriculum even if it is the most natural interdisciplinary approach to science. We propose a study to show that with the aid of astronomy integrating the curriculum for the two above mentioned age groups can be efficiently achieved. We discuss the design of a one week pilot educational program that uses astronomy as an integrating core for the interdisciplinary and transdisciplinary approach to the National Curriculum disciplines and their content. We suggest that by using such pilot programs we can help children enrich their knowledge and gain a deeper understanding of the scientific content taught in school as well as offer students astronomy related content that they would otherwise not have access to. We also discuss the impact and the benefits of implementing such educational programs.

Subject headings

Education: astronomy — education: curriculum — education: interdisciplinarity — education: transdisciplinarity

1. Concluding remarks and perspectives

In Romania, astronomy has been interesting for thousands of years. The dacians, our ancestors had extensive knowledge of astronomy, as proved by the placing of the dacian temples and citadels (Stanescu 2015). The syllabus of our first universities, included astronomy. The first romanian to ever receive a PhD in Paris was Spiru Haret with a thesis in celestial mechanics, entitled “On the invariability of the major axis of planetary orbits”. Later on, Spiru Haret as ministry of education promoted astronomy as a discipline in high school (Schifirnet 2009). However ten years after his reform in education, in the 1920s, astronomy starts loosing its well deserved place in the curriculum (Parvulescu 1926; Theohar 1928).

During the communism (1965-1989), for twenty years (1960 – 1979) the government invested significant resources in education research and achieved tuning the educational system to the eco – nomic reality of Romania (Tsantis & Pepper 1979). During that time astronomy was a discipline of study independent of all the other disciplines which was taught in senior year in high school. After 1989, Romania has been under a perpetual reform in education (Florian & Toc 2018) and astronomy was pushed out of the National Curriculum ceasing to be a discipline of study in Romania. Today, one cannot specialise in astronomy in any of the Romanian universities. Today astronomy is marginalised and often treated as part of other disciplines such as mathematics, physics or even geography.

At international level, the place of astronomy in education is not well defined either. Whereas in most countries the national curriculum includes astronomy content as themes inside school subjects such as natural sciences, mathematics, physics or geography, a very small number of countries actually have astronomy courses in their national curriculum for middle school and high school. There are more and more astronomers reaching out to help education understand the utility of astronomy in our daily lives and help define the astronomy themes important to be known and the ones adequate for the age groups involved in the education process (Percy 2006; Roche et al. 2012). Yet, it is still under debate the actual place astronomy should have in education and whether it should have one at all.

The beauty of astronomy, the interest, the captivation of the students towards it, are not enough to justify making astronomy part of the curriculum. Moreover it should not be about professional arrogance (“my science is more important than yours”), but rather about education and how it can be improved. It should only be part of a national curriculum, if it conveys general knowledge content essential for a complete education or it can be a mean towards achieving transferrable skills and knowledge. Astronomy inspired themes needed in education have prompted Retre et al. (2019) in compiling a book on astronomy literacy. With regard to transferable skills, there are a number of successful projects where students learn about the research process by doing astronomy research themselves (Genet et al. 2016).

In other words, astronomy should be in the curriculum not only because it is beautiful, but because it is smart too. Astronomy is not only the oldest interdisciplinary approach, but also the most natural way of integrating the curriculum (Ficut-Vicas 2018). The stars are an inspiration to us all no matter which discipline we excel in (Percy 2006; Roche et al. 2012). Therefore a blend between astronomy and other sciences can only yield in an interesting practice of interdisciplinarity.

Our Romanian national curriculum is interdisciplinary for the preschool and the primary school children but it abruptly switches to a mono-disciplinary approach for middle school children and continues so during high school and university. The result is that the students become over – specialized in one direction but unable to make connections among the knowledge they have in different subjects. Even more worrisome is the fact that students have started rejecting all the disciplines they do not like, qualifying them as useless and push themselves to very early career choices without having the maturity and the knowledge to make such choices, let alone to take in consideration that the jobs of the future might be very different.

The practise of inter – and transdisciplinarity in Romania, especially at the higher levels of education (middle school and higher) is very scarce (Circa-Chirila & Potoccean 2012) and is not implemented through the national curriculum. In the contrary, our national curriculum has failed to correlate the syllabuses of different disciplines of study, making the acquirement and the development of inter – and trans – disciplinary skills even more difficult. In their study concerning the inter – pluri – and transdisciplinary perspective of students from the Faculty of Physics and the Faculty

of Philology, Craciun et al. (2013) show that future teachers have a difficulty in understanding and practising an inter-, pluri – or transdisciplinary approach in class because they themselves have not experienced one and during their teacher qualifying process they have not been instructed on how to handle such an approach.

We propose an educational programme that uses astronomy as an integrating core for an inter – and trans – disciplinary approach to education. Astronomy's beauty will captivate the students towards giving a chance to disciplines and career options that might otherwise get overlooked. An interdisciplinary educational programme will give astronomy the opportunity to enter romanian schools and address the student's interest for this field in a professional manner.

2. Astronomy for better education

2.1 Why Inter – and Transdisciplinarity in education?

Transdisciplinarity is an invitation ” to cross through, between and beyond the knowledge compar – timentalisation in disciplines of study, to insure the dialogue between different disciplines of study on a common ground” (Suciu 2018). The world we live in and the problems of our daily lives are not monodisciplinary and we do not get to select which problems we like and solve only those. Education prepares students for life and because life is rarely predictable, a flexible, open mind and a set of transferrable skills are essential to succeed.

A student who can connect between different knowledge contents he/she learnt is a student who uses his/her knowledge. Moreover a student able to look at the world as an ensemble of diversities is also able to transfer knowledge, abilities and competences from one field to another in a free and creative manner. The power of the student is in the balance between acquiring new knowledge and creating, visualising links between the knowledge he/she already has.

Tipping the balance on one side yields in the tendency to overspecialise in one unique direction. This tendency can be very dangerous for younger (than undergraduates) students, first and foremost because they push students into big life decisions without knowing, without leaving room for a change of heart later on when a new aptitude surfaces, or when the job they prepared for ceases to exist. Tipping the balance on the other side we end up pushing on integrating and interconnecting and we forget that by neglecting monodisciplinarity we are left with little to nothing to connect.

A healthy educational system is able to balance out monodisciplinarity and inter – and trans – disciplinarity. It encourages children to capitalise on their aptitudes and talents, but also to explore the world and expose themselves to different learning contents and experiences.

2.2 Prelude for Astronomy effect on Education

In my previous research assessing the role of astronomy in romanian education, I designed and applied two surveys, one for teachers and the second one for parents. The surveys proved there is a vivid interest for astronomy among children and both teachers and parents encourage this interest however they often lack the knowledge and the structure within our educational system needed in order to be able to educate children on this topic (Ficut-Vicas 2018).

The surveys were applied to twenty five teachers teaching different age groups, with

different experience in the field from both rural and urban schools and to 17 parents also a very diverse group. In preparation of this educational project, we asked both parents and teachers about the interdisciplinary character of astronomy and that data is only now being published in the following two figures.

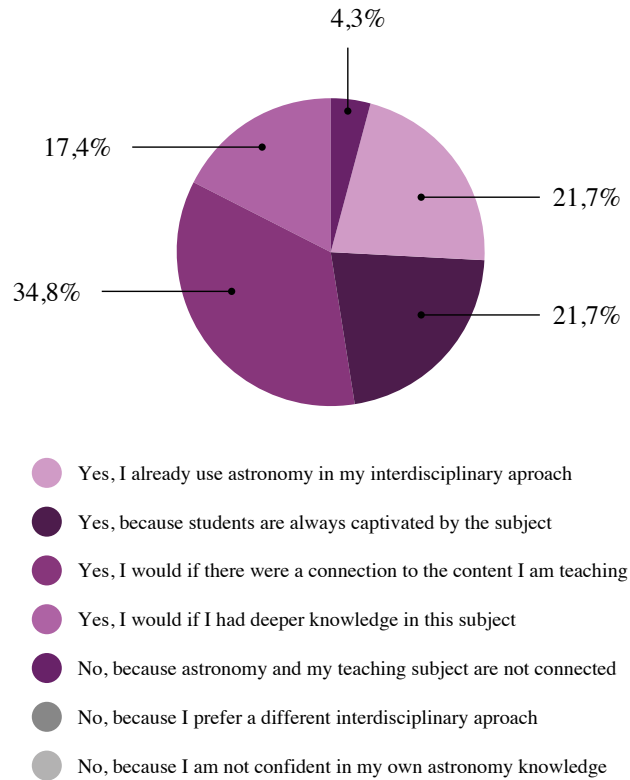


Fig. 1: Teachers' response regarding their use of astronomy in their interdisciplinary approach in class according to the survey we applied.

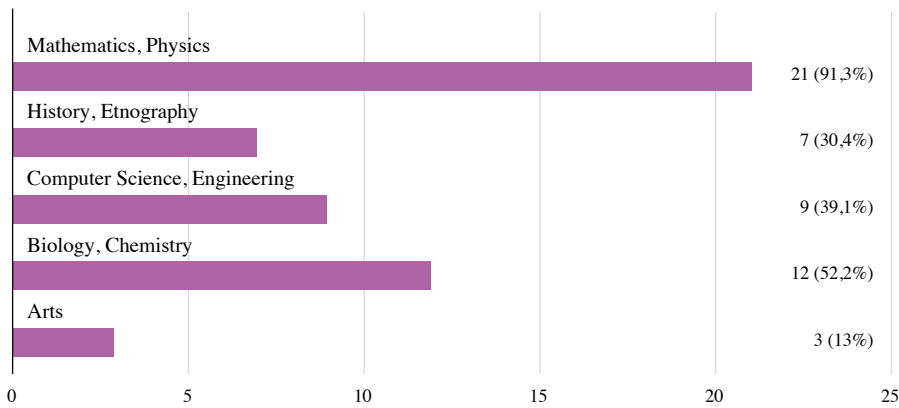
Being asked whether they use astronomy in their interdisciplinary approach in class, as illustrated in Fig. 1 most teachers (34.8%) answered that they would use astronomy if it were related to the content they taught. Some teachers (17.4%) felt unequipped to approach astronomy in class and declared they would use astronomy in their interdisciplinary approach in class if they themselves had more knowledge on the topic. Equal percentages of teachers (21.7%) either already use astronomy in their interdisciplinary approach at class, either they are open to using astronomy at class in order to captivate their students and answer their requests for learning about this field of study. Under 5% of the teachers find that there is no connection between the field they teach and astronomy.

The next question in the survey inquires about which disciplines teachers or parents consider as interlinked (connectable) to astronomy, or in other words which disciplines of study could be combined with astronomy in an interdisciplinary approach. The survey participants are allowed a multiple answer to the question if they consider more than one group of disciplines could be combined with astronomy. Both parents and teachers find that astronomy can be combined with exact sciences such

as mathematics and physics (91.3% of teachers and 100% of the parents), or computer science and engineering (39.1% of teachers and 64.7% of the parents), or with biology and chemistry (52.2% of teachers and 23.5% of the parents). Interestingly teachers would rather link astronomy to biology and chemistry than to computer science and engineering, whereas the parents see things the other way around. When it comes to bringing in astronomy when at class is taught history or ethnography only 30.4% of teachers would consider connecting these disciplines and only 23.5% of the parents. Parents unlike teachers would rather connect astronomy to arts.

Interestingly, these two figures show that although astronomy is not taught in school at all, the great majority of teachers and parents have a sense of the high interdisciplinary character of astronomy. Hence the idea that astronomy can be a useful and efficient integrating core in the inter – and trans – disciplinary approach to educational programs.

Teachers



Parents

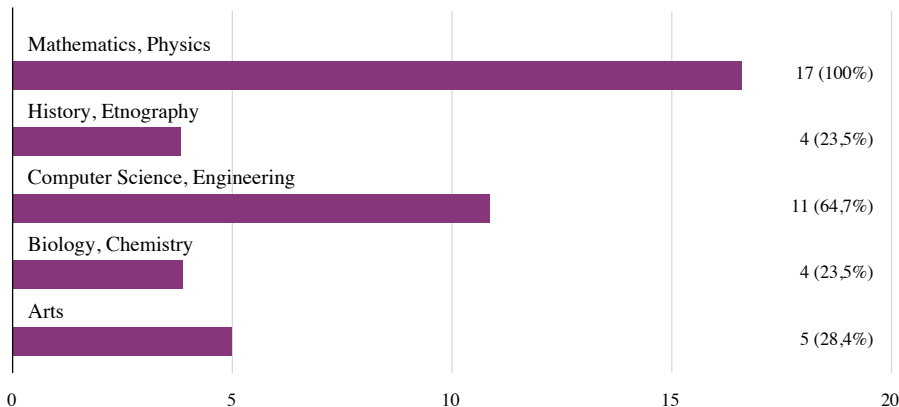


Fig. 2: Teachers' (upper panel) and parents' (lower panel) response to our survey question regarding the school disciplines interconnected to astronomy.

2.3 Discussion

Astronomy deals with all the extensions in space, or beyond Earth of all the other sciences. One can easily use astronomy to build bridges between disciplines and connect with many and quite diverse disciplines. This sort of versatility makes astronomy harder to be contained within its disciplinary borders and contributes to its complexity. This means that students with a poor knowledge background will see it difficult, as they will be suddenly in the position of using very diverse knowledge and combining it in order to understand astronomy content. Moreover, because astronomy intensively uses the knowledge from other disciplines it is often viewed as an applied science to mathematics or physics, rather than a standalone science.

There are indeed a number of themes in astronomy that are essential, however those themes can be handled in the national curricula as themes and do not require introducing astronomy as a discipline in the curricula. Content wise astronomy can be approached in education through themes and if those themes appear in different subjects in a well designed correlated manner they can speak even louder about the interdisciplinary character of astronomy. For example, in Romania, in the 5th grade and the 9th grade we learn in geography about the Solar System. If we would correlate that lesson with say a lesson on the gravitational force in physics and notions of nucleosynthesis in the chemistry lesson we would be teaching very important astronomy content without an assigned discipline in the syllabus. However is important that in a form or another students learn about astronomy as a science before approaching different astronomy themes interdisciplinarily in order to avoid confusion and make sure that the fact that they learn about the Solar System in the geography class for example does not translate to them as astronomy is part of geography.

I propose to turn the disadvantage into an advantage and instead of running away from astronomy because it is different, let's embrace its interdisciplinary character and use it in our educational approaches. Evidently, promoting astronomy as an integrating core in the interdisciplinary approach to educational programs can be beneficial for both education which is able to solve a very stringent problem of integrating the curriculum for certain age groups and astronomy which although is captivating students has difficulties finding a meaningful place in the curriculum.

3. Pilot Educational Program using astronomy to improve education

3.1 The Idea

We designed a one week educational program which explores the interconnections between astronomy and other sciences. This pilot educational program will be implemented by our team in collaboration with the teachers in the two schools that agreed to participate in the pilot program. The program is designed for 7th grade students (age 13-14). For the duration of the pilot program data will be collected for educational research purposes that will allow us to assess the success of the pilot program.

The data collected so far through surveys show that the interest for astronomy is high enough to break the ice and determine schools to try this new approach but also smooth out the difficulty of interdisciplinary practice. Astronomy can, in this way, be part of the curriculum and also contribute to it by enabling interdisciplinary thinking and practice for students and inevitably for teachers too.

3.2 Methodology

Romania is currently implementing at the national level a program called A Different kind of School where students are given a week per school year where they can learn things in other ways than the traditional sitting in the classroom manner. We use the freedom this program gives to schools in choosing how their students spend that particular week and propose the schools an interdisciplinary vision of science focused on the interconnections between astronomy and other disciplines of study.

Table 1: The content of the 5 days educational programme proposed

5 Days 5+ Disciplines and Astronomy

| | |
|--|---|
| <p>Day 1: Chemistry and Astronomy</p> <ul style="list-style-type: none"> — Cosmology and chemical elements formation — Chemical reactions and star formation — Chemical reactions and stellar evolution — Stars as furnaces for the chemical elements of the Universe — Astrochemistry | <p>Day 2: Biology and Astronomy</p> <ul style="list-style-type: none"> — What does life mean? — How do we survive in space? — Space colonization. — Life on other planets Terraforming other planets. — Astrobiology |
| <p>Day 3: Physics and Astronomy</p> <ul style="list-style-type: none"> — Gravitation — Centrifugal force and centripetal force — Unified forces — The elegant Universe | <p>Day 4: Computer Science, Engineering and Astronomy</p> <ul style="list-style-type: none"> — Bird flight — flying devices — rockets — Astronomical instruments — What does astronomy measure? — What data quantity is astronomy handling? — The need for automating. The boundary between real and imaginary. Astronomical data analysis and final products. — Technology transfer between astronomy and other sciences. |
| <p>Day 5: Beyond it all...</p> <ul style="list-style-type: none"> — Astronomy and other sciences: history, literature, ethnography, etc. — Focusing on the transdisciplinary themes — Project presentations — Feedback | |

Because nothing similar has been attempted before in Romania we designed the syllabus of the one week taking into account the existing science knowledge of the students at different levels and the difficulties they have with assimilating the science content of the national curriculum. In table 1 we illustrate the content that will be discussed during the five days. In each of the five days the students explore the border between astronomy and another discipline such as chemistry, biology, physics, computer science and engineering every day being focused around 5 big interdisciplinary and transdisciplinary themes: Cosmology, Life on planet Earth, The effects of gravity, Technology transfer and Measuring the intangible.

The project described here is an on going project and we have finished designing the syllabus and the interviews and are now awaiting for the date assigned by the schools for the implementation of the program. Each school assigns its own date to the A Different kind of School program according to their criteria of making this learning experience as enriching as possible. Because as a pilot program we will be the educational program running during that week for the two host schools, we are bound to the date decided by the school.

The scientific data for this research project will be collected through direct observations and through two interviews that the participants will have to fill in both before and after the one week program. The questions of the survey although are content related, testing the level of understanding the 7th grader have of science concepts they have already learned in class according to the national curriculum, they are in fact aimed at assessing how broad the view of the child is and how many interconnections is he/she able to make using the knowledge they have. As an example of interview items with open answers we mention "give three examples to illustrate the force of gravity" or "explain what light is in your view". We are also interested in how much the child uses his own interests and hobbies and strong points into answering a question, therefore some of the interview items will aim to learn about the child's likes and dislikes, etc. The interviews will give us information about the evolution in time of our intervention and will be the fundament of our quantitative analysis. The qualitative data collected in the interviews will be used in combination with the student portfolios.

During the one week program students will build small portfolios that we will also be collecting since they contain useful information about the evolution of the interdisciplinary vision of the students exposed to the pilot program. In this manner we get to observe how we can improve the motivation and the performance of students in other disciplines by means of an interdisciplinary approach with astronomy as an integrating core.

3.3 Implementation & Risks

One risk in implementing our program is student motivation. Unfortunately there are schools which either cannot afford it financially or are trying to avoid the bureaucratic hassle and offer their students during the A Different kind of School program an experience students perceive as a holiday at school. From the point of view of our pilot study the risk is that such students will not take our intervention seriously and may lack the motivation to get actively involved in our proposed educational program. The risk will be diminished if the content of our program manages to startle their curiosity.

We are implementing this pilot educational program on a small scale, however if we were to implement it on a larger scale, a potential risk could be the teachers implementing it. Teachers are essential in the success of any educational program. Hence difficulties will appear due to the insufficient preparation of the teachers in

both the field of astronomy and the practising of inter – disciplinary at higher educational levels. A way to overcome this is to organise an interdisciplinary team that travels to the interested schools and in collaboration with the teachers at that school implements the program. In this manner students will have access to the educational program even during the process of instructing more teachers in such interdisciplinary approaches to educational programs. If the program is coordinated by one sole organisation, than during the implementation of the program we will be able to collect data through surveys and interviews that will allow us to observe the effects of the program on a longer period of time and to fine tune the program to better address the needs of students.

4. Conclusion

We find that both teachers and parents are open to more astronomy content in schools. Also the teachers interviewed are interested in interdisciplinary approaches through astronomy yet are well aware of their limitations in their own knowledge of the subject and in finding a link between astronomy and their own subject of expertise.

A solution for integrating astronomy knowledge in the curriculum and interlinking it with the other science content our students learn in school has long been sought for. The educational program presented here is a solution for teaching astronomy basic knowledge and at the same time showing the students that the knowledge they acquired through the national curriculum is useful and even more valuable when interconnected. Hence we do not propose transforming all students into astronomers but rather using the appeal of astronomy to help children understand science in general and be driven towards it.

A successful pilot study will push us a step further into at least two other studies that answer some vital questions regarding the feasibility of our proposed solution: Is astronomy better as an integrating core than other sciences? Is one week per year enough for developing and maintaining inter – and trans – disciplinary skills or how should one balance between mono – disciplinarity and inter – and trans disciplinarity timewise?

Our pilot study will likely prompt us to try and implement such an interdisciplinary week program at a national level. Similarly to the A Different kind of School educational program, The Interdisciplinary and Transdisciplinary week program would give middle school and high school students a week to taste the true meaning of inter – and transdisciplinarity and develop the skills they need to make connections, associations and innovate by using all the dimensions of their knowledge.

I thank Prof. Suci L. and Prof. Ciascai L. for all the encouragements and the advice that materialised into this article. I also thank my professors at the masters program for opening for me the door to the field of astronomy education. I am also grateful to Vlad Turcu at the Astronomical Observatory Cluj-Napoca for his support in making astronomy education a direction of research in the Cluj Branch of the Romanian Academy of Science.

References

- Circa-Chirila, C., & Potocean, O. 2012, Epcisi curente culturale europene. *O educatie transdisciplinara intro Scoala Altfel* (Editura Scoala vremii)
- Craciun, D., Oprescu, M., & Oprescu, F. 2013, *Journal of Educational Sciences and Psychology*, III (LXV), 1

- Ficut-Vicas, D. 2018, *Romanian Review of Geographical Education*, 7, 31 Florian, B., & Toc, S. 2018, *European Education*, 50, 320
- Genet, R., et al. 2016, *Society for Astronomical Sciences Annual Symposium*, 35, 59
- Parvulescu, C. 1926, *Buletinul Asocatiei Observatorilor Romani*, 13–14, 1
- Percy, J. R. 2006, *JAAVSO*, 35, 248
- Retre, J., et al. 2019, *Big Ideas in Astronomy*. A proposed Definition of Astronomy Literacy (Creative Commons Attribution 4.0 International (CC BY 4.0)), IAU Education Commission C1
- Roche, P., Roberts, S., Newsam, A., & Barclay, C. 2012, *SCHOOL SCIENCE REVIEW*, 93, 63 Schifirnet, C. 2009, *Spiru Haret, the reformer of Romanian society*, Vol. 1 (Editura Comunicare), 13 – 42
- Stanescu, F. 2015, *Astronomical Orientation in the Ancient Dacian Sanctuaries of Romania*. (Springer, New York, NY), 1365 –1375
- Suciu, L. 2018, *Stephane Lupasco, La confluenta cercetarilor transdisciplinare* (Presa universitara clujana)
- Theohar, M. 1928, *Natura*, 17, 15
- Tsantis, A. C., & Pepper, R. 1979, *Romania – Industrialization of an agrarian economy under socialist planning*, Vol. 1 (A world Bank country study), 168 – 171

The determination of the size of the Moon using lunar eclipse photos

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Abstract

In our contribution we present activity: The determination of the size of the Moon using lunar eclipse photos. The idea of the proposed activity is based on the original concept of Earth's shadow observation during lunar eclipse proposed by ancient Greeks. The study of the photos taken during lunar eclipse enables to find how big is the Earth's shadow comparing with the Moon and further determine the dimensions of the Moon. We recommend to include this activity in the mathematics lessons in part relating to circle defined three points at lower secondary school. The application of already known mathematical procedures and also constructive approach are needed to solve it properly. The benefits of this activity are the connection of mathematics with astronomy, the application of mathematical procedures in the context of astronomy and obtaining new information about the Moon.

Keywords

Lunar eclipse, photography, Moon radius, circle, ratio

1. Introduction

The Universe is one of the most attractive topics for people. Neverending questions about the Universe have led us to think how it would be possible to implement astronomy in the education process. The Slovak state education programme for physics does not contain topics from astronomy. In the education process pupils learn about the Solar System, Earth's rotation and movement of the Earth around the Sun on the age level 8-10 years in biology lessons [1]. One way how to implement astronomy themes in the education process is to include the specific parts of astronomy in mathematics lessons.

The activity: the determination of the size of the Moon using lunar eclipse photos was prepared to be included in mathematics education. We recommend to include the activity on the age level 13-14 years, when pupils solve ratios and proportions and when they are familiar with the construction of circle defined by 3 points. The activity offers pupils not only the possibility to apply the acquired mathematical procedures, but also points out the connection of mathematics with astronomy because the activity will bring pupils the original concept of calculation of the Moon size proposed by ancient Greeks. It is possible to realise the activity in different ways and it is only the choice of the teacher which one he prefers. The common theoretical background in astronomy is needed both for the teacher and for the pupils in case of each of the chosen ways. Theoretical background consists of knowledge about the movements of the Earth and the Moon in the Solar System (comprising also lunar phases), about the specific conditions when it is possible to observe the different types of eclipses in general and about how they differ between each other. Our activity is based on the analysis of the observations of the partial lunar eclipse. The concept of the analysis was used also by other authors [2], [3].

2. Activity

At the beginning of activity the teacher shows to the pupils the photography of the partial lunar eclipse. The task of the photography is to wake up the curiosity and interest of pupils about the phenomenon. The discussion supervised by teacher should take place. The objective is to understand the phenomenon they can see in the photography. During the discussion the teacher can pay attention to the explanation of the movements of the Earth around the Sun and of the Moon around the Earth. The teacher should be prepared also for the potential questions concerning the origin of lunar phases. After the basic concept of the formation of lunar eclipses will be presented.

The teacher should pinpoint the fact that the lunar eclipses can occur only during the full Moon. We recommend to maintain the three-dimensional representation of entire phenomenon. For example see Figure 1.

The reason is that the usual explanation of the formation of eclipses presented to pupils based on two dimensional simplification can be quite confusing. We assume that this concept can lead to the misunderstanding that both the lunar and solar eclipses occur every lunation cycle and thus we could see them every month. For that reason the teacher should have prepared detailed working sheets.

After the introductory discussion, the proposition of the problem solution follows. Each pupil in the class gets the photography of the partial lunar eclipse. The aim is that the pupils now propose the way how to find the dimensions of the Moon, especially its radius using the photography. The pupils need pencil, compass, ruler and colored pencils or pens (simpler orientation in the photography) for the exercise. The goal of the teacher is to lead the pupils to the correct solution using appropriate

questions. The activity is based on asking the questions, which don't directly reveal the solution. On the other side they should gradually direct the pupils to the solution.

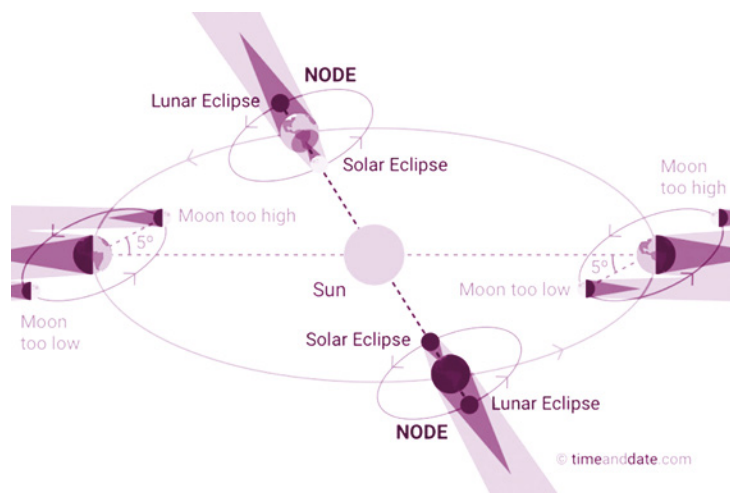


Figure 1: Three-dimensional representation of the lunar eclipse (available at <https://www.timeanddate.com/eclipse/partial-solar-eclipse.html>).

Guiding questions:

- What phenomenon is possible to see in the photography?
- What is the essence of the phenomenon? Which celestial objects can we see in the photography?
- What are the geometrical objects in the photography?
- Are we capable to draw these objects?
- What are the properties of the circle which can be used for problem solving?
- How would it be possible to determine the value of the lunar radius using the measured radii and knowing the actual radius of the Earth?

The objective of the enumerated questions is to lead the pupils to each step of the solution. We propose to proceed to the solution of the activity itself only after finding the solving process. Each step of the process is important and it is necessary to pay attention to it.

Problem solving requires to apply the knowledge of geometry of circle. If 3 points on the circle are known, it is possible to find the center of the circle. Crucial part of the construction is the choosing of 3 points on the border of each circle (see Figure 4). Resulting value of the Moon radius depends on the precision with which these points are determined. The drawing of each circle follows after the selection of needed points. The pupils are capable to find the center of the circle if 3 points of this circle are known.



Fig. 2: Partial lunar eclipse with the panorama of the Bratislava castle observed on 21. January 2019, Bratislava, Slovakia. Photography taken by Roman Vačar on 21. January 2019.



Fig. 4: The chosen points on the border of each circle.

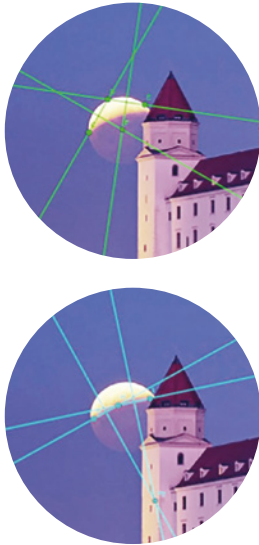


Fig. 5: Visualization of the searching for the centers of both circles, Moon (upper) and Earth (lower).

They have to draw the axis of each chord. The point where the chords intersect is the center of the circle and the 3 used points belong to this circle (see Figure 5). After finding the centers follows the construction of both circles. The final steps are drawing and measuring Moon and Earth radii directly in the picture.

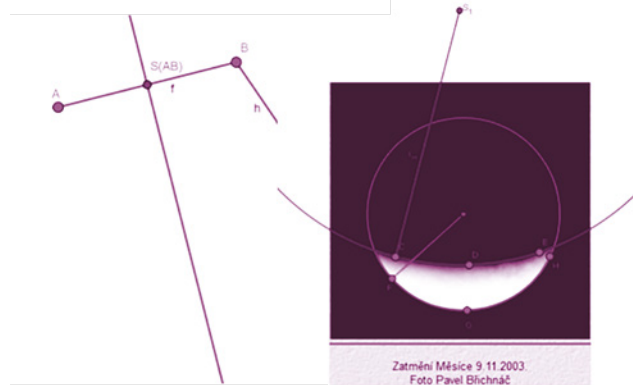


Figure 3: Searching for the center of the circle. Photography taken by Pavel Břichnáč in 2003.

The pupils know by experience that the dimensions of the objects in the photography are diminished comparing to the real dimensions of these objects. They have to keep in mind this fact while solving the exercise. The radii of the Moon and the Earth are diminished. However at the same time their ratio is the same as of the real radii. In this way the pupils can really simply express following ratio:

$$\frac{R_E}{R_M} = \frac{r_E}{r_M}$$

where R_E and R_M denote the real radii of the Earth and the Moon respectively and r_E and r_M are the radii obtained from the analysis of the photography. The pupils should be already familiar with the real Earth radius. If the value is unknown, it is possible to directly tell them this information. Afterwards during other mathematics lessons it is possible to explain the idea how to find the Earth radius using the original concept of Eratosthenes based on the measurements of the length of shadow during summer solstice. At the moment there are 3 known values from equation 1 and using them the pupils should find the solution. For some pupils expressing the unknown value from the equation can be a difficult task and the help of the teacher could be needed. To express the unknown value of the Moon radius we can rewrite the equation 1 in the form:

$$R_M = R_E \frac{r_M}{r_E}$$

After the geometrical construction we found using the photography in Figure 2 the radio of the Moon and the Earth. Our resulting values are $r_M = 3,4$ cm and $r_Z = 8,7$ cm. Inserting these values in the equation 2 we obtain the value of Moon radius $R_M = 2489$ km. We assumed $R_E = 6371$ km and we approximated Earth as a perfect sphere.

3. Analysis using GeoGebra software

Alternatively, it is possible to solve the exercise using GeoGebra software (available at <https://www.geogebra.org/>). This software serves as an interactive tool for drawing. It is mainly applied in the education process. The advantage of using GeoGebra for the proposed activity is faster and more precise drawing. Of course only in case if the pupils are familiar with the software. If the pupils hadn't worked yet with GeoGebra, it could have been used just like a useful tool for a teacher. A teacher can draw each step of the construction with pupils. It is also an opportunity to check if their results are consistent. The important advantage is that a teacher can prepare this activity in advance and after it is easy to display the construction step by step during the lesson.

Analysing the Figure 2 using Geogebra software we obtained following values for each radius: $r_E = 1.02$ and $r_M = 0.35$ (see Figure 6). At this point, the teacher should discuss with the pupils why found radii are dimensionless. If it is necessary to work always with the basic SI units and if it is necessary to always know the concrete dimension of the analyzed parameter.



Figure 6: The results of our construction.

Looking at the equation 2, it is possible to see that the ratio of the radii is important. The found values for the radii on the photo have the same dimensions and in the end they reduce.

Using the real Earth radius $R_E = 6371$ km and the found values of Earth and Moon radii in the photo we obtain Moon radius

$$R_M = 6371 \cdot \frac{0.35}{1.02} = 2186 \text{ km.}$$

4. Discussion

The actual Moon radius is approximately 1737 km. It is possible to directly see that the calculated and real values of the radius are different. The calculated value of the parameter is dependent on the precision with which the points on the circle border were chosen. Each pupil is going to find different value of Moon radius. The other very important fact is that during whole activity we considered the Sun as a point source of light. This simplification principally causes inaccuracies in our calculation comparing with the real value. The Earth radius in the distance of the Moon is slightly smaller than the real Earth radius. The teacher should lead the discussion with its pupils in purpose to explain them where do this inaccuracies come from. The extension of the activity could contain the way how to solve the problem considering the Sun as the source of light with some specific angular dimensions, in case of Sun around 0.5° .

However we suppose this could be presented mainly to older students.

5. Conclusion

The main aim of our contribution was to show how it is possible to implement astronomy themes in education process at lower and upper secondary schools. After preliminary implementation of the activity we suppose that pupils had the biggest difficulties expressing the ratio. We recommend the teacher should be ready to guide the students to express the ratio. On the other side we would like to pinpoint that the activity attracted the attention of the pupils and stimulated their curiosity. Based on our experiences from utilization of the activity we suggest that the astronomy can be included in maths lessons.

Acknowledgement

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References

- P (Slovak national institute for education). *Slovak education programme: Natural science* [online.] Bratislava: SNIE, 2014 [cited 2019-09-12].
- F. Kundracik. Voj predstavenie o veľkosti slnečnej sústavy aiacke experimenty, 2015 [cited 2019-09-12]. <https://www.youtube.com/watch?v=yvE-4FASwwI&fbclid=IwAR1km6o4zN8IqHUK4dc0nD77EmYlsArIxOfSmS-V4nskNV0MxZ9xkBbBOZo>.
- M. P. Jimenez. Educational activity, measuring the size of the shadow of the Earth (total lunar eclipse 2014). <https://gloria-project.eu/wp-content/uploads/2014/04/2014lunar-eclipse-crater-shadows-en.pdf>.

Learning of the Galaxy with the Mitaka system in classes of a junior high school

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Abstract

The Mitaka system, developed by the National Astronomical Observatory of Japan (NAOJ), provides 2D or 3D views from different viewpoints other than the Earth. In this paper, we studied the effect of using Mitaka with active shutter glasses in learning the Milky Way galaxy in classes of a junior high school in Japan. We expected that students learned the Galaxy more effectively with Mitaka, though our post-tests for comprehension of the Galaxy did not show any significant difference between classes with Mitaka (total $n=77$) and without Mitaka ($n=39$). However, we found that the students were more interested in the Universe if they used Mitaka. In addition, ninety-two percentage of respondents in classes with Mitaka answered that they thought Mitaka was effective in learning the Galaxy. We can conclude that the Mitaka system is a quite useful tool to inspire them to study in those classes.

1. Introduction

To understand astronomy, it is often necessary to observe astronomical objects from 3-dimensional (3D) viewpoints. On the Earth, however, the astronomical objects are projected on sky (celestial sphere), thus we just see them only in 2D plane. We therefore need information on one more dimension, i.e. distance from the Earth. Astrono-

mers have struggled to obtain methods to determine the distances to objects, e.g. the transit of Venus across the Sun for the astronomical unit (distance to the Sun), annual parallax for stars, the Hubble-Lemaitre's law for galaxies, etc. (e.g. Brendzen et al. 1976 for our and external galaxies). This story also holds for students in schools, as they also have difficulties in understanding the 3D structure of the Universe (Yu and Sahami 2008). Thus it is a challenge to provide them good material to understand astronomy in addition to 2D books and boards (Slater & Tatge, 2017, pp. 94-97).

Stereoscopic view is one of the methods to provide 3D information, based on the binocular parallax in human vision, and it has used since the 19th century mainly for entertainment such as 3D films (Price et al. 2015 for a review). A possible usage of the stereoscopy was discussed as a tool for science education also in the 19th century (Wheatstone, 1838), though academic research for stereoscopy is limited in recent decades (Price et al. 2015). Unfortunately, not all the studies showed the effectiveness, e.g. Cid and Lopez (2010) did not find any advantages in learning the lunar phase. The negative results may be due to that the stereoscopy works only when the uniqueness of stereoscopy is required and other methods are not useful (Price et al. 2015). The most effective usage of stereoscopy might not have been found yet.

Chastenay (2016) stressed the importance of different points of view other than the Earth, which Chastenay called as "allocentrism" as opposed to "geocentrism". Using the advantage of a modern digital planetarium that can easily make a view from space, Chastenay (2016) studied how students with age of 12-14 learn the lunar phase, and concluded that the students learned more effectively with different viewpoints. Chastenay's study implies that the stereoscopy may not be necessary if the views from space are used. Apparently, more studies are needed to confirm the effectiveness of stereoscopy and different viewpoints.

Mitaka is software developed by the 4D2U²¹ project of NAOJ for 3D visualization of the Universe in various scales with observational data as well as theoretical models (Kokubo et al. 2005, Hayashi, et al. 2012, Kato 2017, Nemoto et al. 2014, also see Mitaka-webpages). Mitaka has been developed since 2003, and ver.1.6.0b is released at present. Mitaka is now available not only in Japanese, but also in nine languages! The recent version "Mitaka for VR" is compatible with a head-mounted display, and it provides a virtual reality environment (Kato 2017). Mitaka originally developed for a theater in NAOJ campus in Tokyo, but it also works in a Windows PC, and projects images onto a screen in various ways. The Mitaka system thus has significant potentials to help students to learn astronomy.

We have studied the effect of using Mitaka on the 3rd grade (K9) science classes in a junior high school in Japan, where the theme is our Galaxy. Galaxies are important objects to understand the Universe, though not much attention is paid in school classes. In Japanese national curriculum, the Galaxy is taught in the final part of grade K9. The Milky Way is hard to see in urban areas today, and students are not familiar with it. It is thus a challenge to study how to learn/teach the Galaxy and galaxies in classes. In our study, one of the authors, Misato Mori, gave tuition in classes of the Sakaide Junior High School attached to the Faculty of Education, Kagawa University, in November 2018, and this paper is based on the results in those classes. Other studies performed by us with Mitaka were reported in Matsumura (2016, 2017, 2018), but they are all in Japanese.

2. Our classes with Mitaka

We used 3D view in a screen with a special projector that display two images simultaneously. Those two images were produced by Mitaka installed in a Windows PC. Each student wore active shutter glasses (Fig.1).

In two classes (total n=77) of K9 grade, we used Mitaka, while not in another class

21 According to Kokubo et al. (2005), 4D2U means "4-Dimensional Digital Universe" and also "4D to you", where 4D includes 3D in space and 1D in time.

(n=39) for a control group. We took two class periods (50min. x 2) in each class, and the contents used in those periods are explained in Tables 1 and 2. In the former classes, Mitaka was used to explain the Universe with varying the scale from the Earth to the cosmological horizon in the 1st period, and the appearance of the Galaxy in seasons was discussed with using Mitaka in the 2nd period. Before those classes, Akihiro Washibe, one of the authors, had taught the Sun-Earth-Moon system and objects in the Solar System in all the classes.

Table 1: Class of the 1st period: “The Galaxy and its relation to the Solar System”

| Items | Contents | Material etc. |
|---|---|---|
| The Galaxy | <ul style="list-style-type: none"> — Stars make a large cluster, called as the Galaxy. — The Galaxy is a disk in shape, and it makes spiral. — Distance unit: light-year. | <ul style="list-style-type: none"> — Pictures of galaxies — Manufactured model with a CD-disk — Explanation of light velocity |
| The Solar System | <ul style="list-style-type: none"> — The Solar System is a heliocentric system. — The Solar System includes the Sun, planets, satellites, etc. | — |
| Explanation of the Universe with Mitaka | <ul style="list-style-type: none"> — The density of stars is high near the galactic center, and vice versa. — Many galaxies exist other than our Galaxy. — Distances between stars are large. The Solar System is small compared with stellar distance. — The Sun is much smaller compared with the size of the Solar System. — The Earth is much smaller compared with the Sun. | <ul style="list-style-type: none"> — Explicitly explain the position of viewpoint, to understand the Galactic structure. — Show the Jupiter’s satellites, to explain what are satellites. # Ask them not concentrate too much for avoid feeling dizzy. |

Table 2: Class of the 2nd period: “Where are we within the Galaxy?”

| Items | Contents | Material etc. |
|-----------------------------|---|---------------|
| Appearance of the Milky Way | <ul style="list-style-type: none"> — The Milky Way is an assemble of stars. It appears in summer evenings. | — |



Fig. 1: Mitaka system in our class (upper), and active shutter glasses (lower).

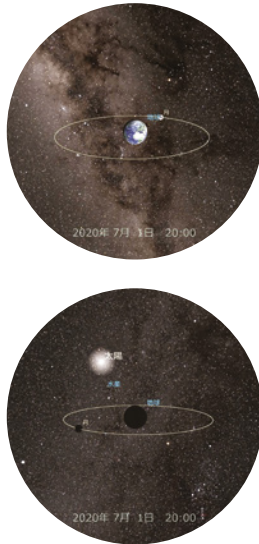


Fig. 2: (Upper) view outside of the Earth in July, with the Sun behind you. From the night side of the Earth, i.e. far side in this view, we see summer constellations and the Milky Way in a direction of the center of the Galaxy. (Bottom) same as upper, but from a standpoint that Sun is in front of you.

| | | |
|---|--|--|
| <p>What is the Milky Way?</p> <p>It is (a part of) the Galaxy.</p> <p># discussion in small groups.</p> | <ul style="list-style-type: none"> — The Milky Way is what we see the Galaxy in an edge-on direction. — Many stars are present, and they appear as a band. — The Milky Way in the summer evening sky is brighter, but it appears also in winter, and is fainter. | <ul style="list-style-type: none"> — Manufactured model with a CD-disk — Explain the reason why the Milky Way appears in a band. — Pictures of the Milky Way in summer, and that in winter. |
| <p>Why the Milky Way is fainter in winter?</p> <p># discussion in small groups.</p> | <ul style="list-style-type: none"> — The Solar System is far from the galactic center. The appearance of the Milky Way is different in directions. — The Earth revolves around the Sun, so the direction of the night sky is different between summer and winter. | <ul style="list-style-type: none"> — White boards for discussion in groups. |
| <p>Study with Mitaka</p> | <ul style="list-style-type: none"> — A bright Milky Way can be seen from a viewpoint of outside of the Galaxy, in the direction to the center. — The Milky Way is less bright in the direction of the anti-center of the Galaxy. — As the Earth revolves, the direction of the night sky changes. In the night sky of winter, we see in a direction of the anti-center of the Galaxy. | <ul style="list-style-type: none"> — Move the direction of view 360 degrees, along the Galactic Plane. It shows the Milky Way goes across the whole sky, and the galactic center is bright. — The direction of the night sky varies, as the Earth revolves around the Sun. |

In the 2nd period, we discussed the reason why the Milky Way in the summer evening is brighter than that in winter. After discussion in small groups, students observed the Milky Way from viewpoints outside of the Earth with Mitaka (Fig.2), and they are asked to explain why we see different part of the Milky Way in different seasons.

3. Results and Discussion

3.1 Interests in the Universe

We evaluate the effect of Mitaka with taking pre – and post-tests. We found that the students were more interested in the Universe after the classes even without Mitaka (Fig.3 right). However, with using Mitaka, we see that the ratio of “much interested” with Mitaka (52%, 40 in 77, red in Fig.3 left) is larger than that without Mitaka (38%, 15 in 39, red in Fig.3 right). Also noted is that those who answered “not interested” and “not interested at all” in the post-tests are almost none with using Mitaka (2.6%, 2 in 76, pale blue in Fig.3 left), while a fraction is recognized for the class without Mitaka (18%, 6 in 39, pale and dark blue in Fig.3 right). Unfortunately, the χ^2 test did not show that those differences were statistically significant at a level of 5%. Those tendencies do not seem to depend on gender, but male students may be more interested in this subject (Fig.3).

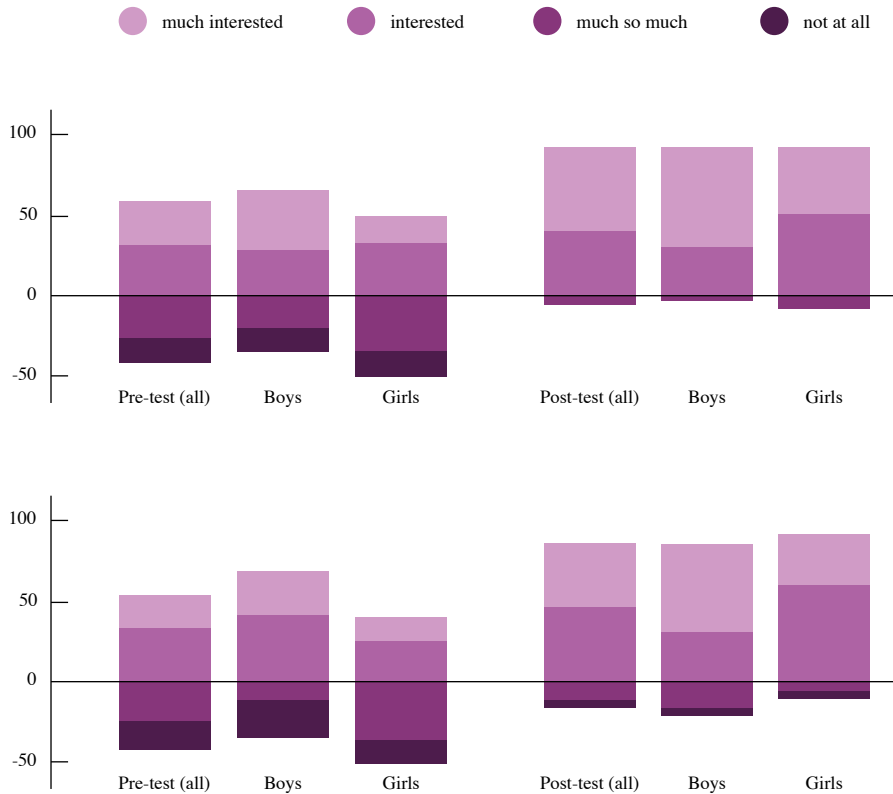


Fig.3: (Upper) results of questionnaire about students' interest in the Universe before/after classes with Mitaka. Those who interested very much (indicated by light pink) increased after with using Mitaka. (Below) same as left but for classes without Mitaka. See text for details.

3.2 Understanding of the contents

We asked students to explain the reasons (1) why the Milky Way appears as a band in sky, and (2) why the appearance of the Milky Way differs between summer and winter. For both questions, almost all the students wrote correct answers. We did not appreciate difference in their answers between classes with and without Mitaka. This result suggests that the questions are too easy for them to answer.

If the interpretation of the result is correct, then it suggests that further usage of Mitaka may be possible, i.e., we may teach more details on the Galaxy. Viewing the images by Mitaka, we see not only stars but also dark nebulae that are concentrated in the Galactic Plane. If we may ask students to pay attention to dark clouds, they would recognize the different distribution of stars and clouds. Then we might extend our story in classes to the relation between gas (clouds) and stars, so that we could talk about star formation, death of stars, heavy metal creation etc., with using Mitaka.

3.3 Evaluation of Mitaka by students

In the post-test, we also asked students about the effectiveness of Mitaka in their learning of the relation between the appearance of the Milky Way and seasons. Ninety-two percentage of respondents (n=77) answered that Mitaka was “effective” (23)

or “very effective” (48). This suggests that Mitaka helped their learning significantly.

Reviewing those results, we can conclude that the Mitaka system is useful to learn/teach our Galaxy. However, we should note that we had a few negative comments: a student wrote that it was hard to understand because too many objects appeared at the same time in the screen. Another student wrote that she felt dizzy with stereoscopic view. Those comments imply that we still have challenges in using Mitaka in classes.

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References

- Berendzen, Richard; Hart, Richard; Seeley, Daniel, 1976, “Man Discovers the Galaxies”, *Science History Publications*
- Chastenay, P. 2016, “From Geocentrism to Allocentrism: Teaching the Phases of the Moon in a Digital Full-Dome Planetarium”, *Research in Science Education* 46, pp.43-77
- Cid, X.C. & Lopez, R.E. 2010, “The impact of stereo display on student understanding of phases of the Moon”, *Astronomy Education Review*, 9, 010105
- Hayashi, Mitsuru., Kato, Tsunehiko, 2012, “Universe view Mitaka1.2.1” *Tenmon-Kyoiku (Astronomy Education)*, 24, 50 (in Japanese)
- Kato, Tsunehiko, 2017, “Experience of Virtual reality Universe with “Mitaka” software”, *Proceedings of the 31st Meeting on Astronomy*, 193 (in Japanese)
- Kokubo, E. et al. 2005, “4-Dimensional Digital Universe Project”, *Journal of the Korean Astronomical Society*, 38, 153.
- Matsumura, M. 2016, “Astronomy Education with Planetarium: from geocentric to allocentric perspective”, *Proceedings of the 30th Meeting on Astronomy*, 225 (in Japanese)
- Matsumura, M. 2017, “Astronomy Education with Planetarium: Study of Venus with Mitaka”, *Proceedings of the 31st Meeting on Astronomy*, 166 (in Japanese)
- Matsumura, M. 2018, “Astronomy Education with Planetarium: Study of the Galaxy with Mitaka”, *Proceedings of the 32nd Meeting on Astronomy*, 265 (in Japanese)
- Mitaka webpage: https://4d2u.nao.ac.jp/html/program/mitaka/index_E.html
- Mori, M. 2019, graduation thesis, Kagawa University (in Japanese).
- Nemoto, S. et al. 2014, “Stereoscopic 3D Projections with MITAKA: An Important Tool to Get People Interested in Astronomy and Space Science in Peru”, *Sun and Geosphere*, 9 (2), 115.
- Price, A., Lee H-S, Plummer, J.D. SabbaRao, M. Wyatt, R. 2015, “Position Paper On Use Of Stereoscapy To Support Science Learning: Ten Years Of Research”, *Journal of Astronomy & Earth Sciences Education* 2, 17
- Slater, T. F., Tatge, C. B., 2017, “*Research on Teaching Astronomy in the Planetarium*”, Springer
- Wheatstone, C., 1838. “Contributions to the physiology of vision. Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision”. *Philosophical transactions of the Royal Society of London*, 371-394.
- Yu, K.C., Sahami, K. 2008, “Visuospatial astronomy education in immersive digital planetariums”, *In Communicating Astronomy with the Public 2007: Proceedings From the IAU/National Observatory of Athens/ESA/ESO Conference 8-11 October 2007*, eds. L. L. Christensen, M. Zoulias & I. Robson pp. 242-245, ESA/Hubble.

Solar X-Ray Flare Monitoring for Upper-Grade High School Education

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Abstract

The influence of solar X-ray radiation on terrestrial radio communication was found in the early 20ies century, but was not understood immediately. Radio communication was a challenging topic back then, and became quickly a topic taught in science classes at school. Half a century later – with the start of the space age – it became evident that studying Earth's upper atmosphere would answer this question. Solar and other cosmic radiation is responsible for the condition of the ionosphere and the cause of black-outs in long-range radio communication. Today, most of the ionospheric very long frequency (VLF) radio propagation phenomenon are known and presumably almost completely understood, though it stays a challenging topic listening to the ionospheric disturbances caused by our Sun.

Teaching Earth sciences and astronomy at upper secondary school level offers students interesting, hands-on and challenging experiments. The aim of the InFlaMo-Project is to provide an inexpensive, high-tech experiment combining astronomy, Earth science as well as applied calculus knowledge.

1. Introduction: How to motivate young people to study solar flares?

What makes communication possible in the modern age? That would most likely be the question asked in classrooms. One part of the answer is indeed modern high-tech radio components. The recent development of low-cost software-defined radio wave receivers (SDRs) [S. Schade et al., 2010, E.-G. Schweppe, 2011] is an on-going process and opens many new opportunities for applications in people's daily lives and in education. Most people carry such an SDR as one integrated component build into their mobile phone. Despite the fact that most school students utilize their mobile phones frequently, it is obvious that they are not aware of the build-in technology of their mobile devices, e.g. radio communication devices. On the other hand, it is commonly known that the radio communication is sometimes disturbed and therefore vulnerable. Here we found an unusual approach to make young people aware on topics such as solar-terrestrial interactions – also called space weather.

Monitoring Earth's lower ionosphere by utilizing VLF monitors, which are based on SDR technology, offers new indirect insights into what happens on the Sun. Many various natural phenomena of Earth's climate as well as our Man-made radio communication are influenced by the Sun and its phenomena such as solar flares near its surface.

Therefore, one aim of this paper is to reach out to an educator community and to offer the InFlaMo project (www.inflamo.org) and its data for educational purposes. The other aim is to enlarge the network of ground-based multichannel SDR-receivers. With this rather inexpensive method monitoring the state of the ionosphere and recording the appearance of solar X-ray flares can be made available for usage in classrooms.

2. Background: What is the InFlaMo Project?

The InFlaMo project monitors the space weather situation via ground-based and satellite measurements. From the ground, it is possible to detect sudden ionospheric disturbances (SID), which are also called the Dellinger effect, or sometimes Mogel-Dellinger effect [D. Kenneth, 1990]. SID is caused by solar X-ray radiation at ionospheric heights and coincides with the appearance of solar X-ray flares. The fade-outs are characterized by a sudden onset and the following recovery which can take from a few minutes to several hours. Earth's upper atmosphere allows us only to view our Sun indirectly and the phenomena appearing on its surface. Being outside the Earth's atmosphere provides a direct view of the Sun. This is archived by using space probes and satellites. For the InFlaMo project, the NOAAs GOES solar X-ray satellite data is used as a reference.

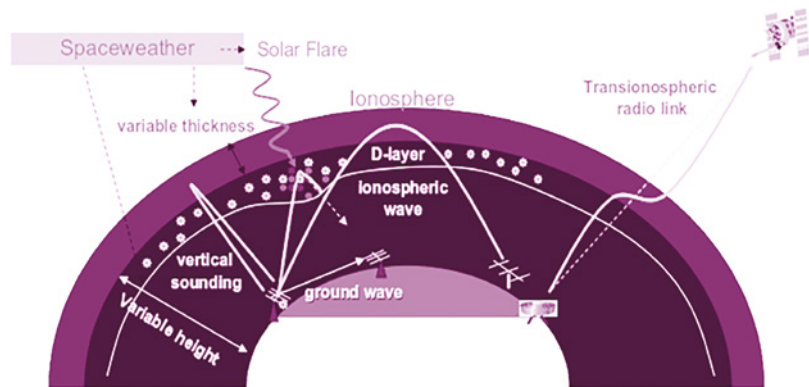


Figure 1. The figure shows a sketch of Earth's upper atmosphere, ground-based instrumentation (radio transmitters, sounders and radio receivers), space instrumentation (satellites) as well as wave propagation. Earth's ionosphere is a variable system with variable thickness and electron distribution (profile) depending on space weather events (solar activity, e.g. solar X-ray flares).

By comparing both direct (space-based) and indirect (ground-based) observations, a great deal of information can be provided. Especially, at times when the availability of space-based information is not guaranteed, due to active space weather conditions, which may limit the trans ionospheric radio link to research satellites, ground-based observations are the only option. At the InFlaMo project, we consider this matter by learning mother nature's language.

When a solar flare occurs on Sun (Figure 2), a blast of intense ultraviolet and X-ray

radiation hits the day-side of the Earth 8 minutes later.

Hard solar X-rays will penetrate down to the D-region, releasing electrons that will rapidly increase absorption, causing a High Frequency (3 – 30 MHz) radio blackout. During this time Very Low Frequency (3 – 30 kHz) signals are reflected by the D layer instead of the E layer, where the increased atmospheric density is usually increasing the absorption of the wave and thus dampen it. As soon as the end of the X-ray, the SID or radio black-out ends as the electrons in the D-region recombine rapidly and signal strength returns to normal.

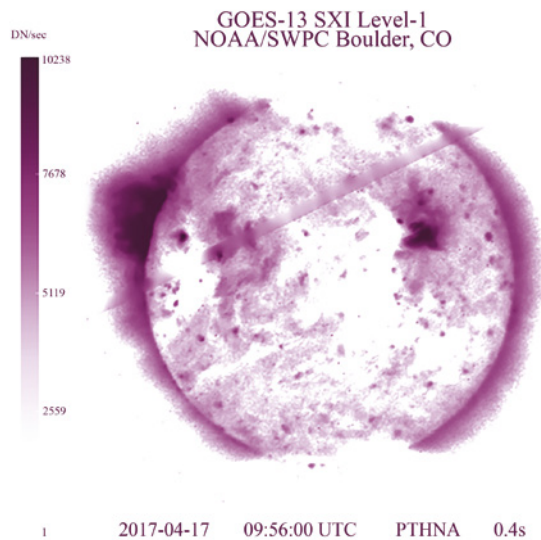


Figure 2. Shows the Sun as seen from the GOES 13 satellite on April 17th, 2017 at 09:56 UTC. A strong solar X-ray flare is visible in the upper left side of the Sun (credit NOAA/ SWPC).

3. Measurement technique

For the monitoring of SID events, a VLF radio transmitter and a receiver are needed. There are plenty of those transmitters operated by national agencies or the military for long-range communication. We are interested only in the variation of a more or less known standard signal. This variation of this field-strength is a measure of the phenomena occurring in the ionosphere. There exist various receiver networks to detect and monitor SIDs. The principle logic is shown in Figure 3. They all consist of a VLF radio receiver and an antenna [Roelof Bakker, private communication]. Due to limitations, when it comes to the best location, we have developed for the InFlaMo project a compact and autonomous operating system, which can be placed at remote locations. It consists of an active antenna, a software-defined radio and the latest single-board computer (Figure 4.1 and 4.2; Raspberry Pi 4 Model B with GSM functionality added). This system is transmitting the data back to the central server, where it is processed on an hourly base and made available on the Internet.

An SDR is a broadband radio wave receiver where components that have typically been implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. For the InFlaMo project, an amateur SDR (Figure 4.4) with a broad bandwidth from about 10 Hz to 60 MHz was chosen. Though it

is only used for the frequency range between 10 and 50 kHz at a sampling rate of 1 second and average signal bandwidth of 50 Hz.

4. Data and data analysis

The InFlaMo project has been operating continuously at its primary location Bentzin (53.95° N 13.28°E) in northern Germany since 2012 – the solar activity maximum phase of solar cycle 24. The temporal operation of other stations was established at Moscow / Russian Federation and at Sodankylä / Finland for some time. Since June 2019, a new station was established at the Ionospheric Observatory Panska Ves, Czech. Here, only data from the main location is used. In particular, the selected amplitude measurements of the relative field strength from the following VLF transmitter stations (call sign, country, frequency, latitude, and longitude) are used:

- HWU, France, 20.90 kHz, 46.71°N, 1.24°E GQD,
- Great Britain, 22.10 kHz, 54.73°N, 2.88°W DH038,
- Germany, 23.40 kHz, 53.07°N, 7.62°E NAA,
- USA, 24.00 kHz, 44.64°N, 67.28°W

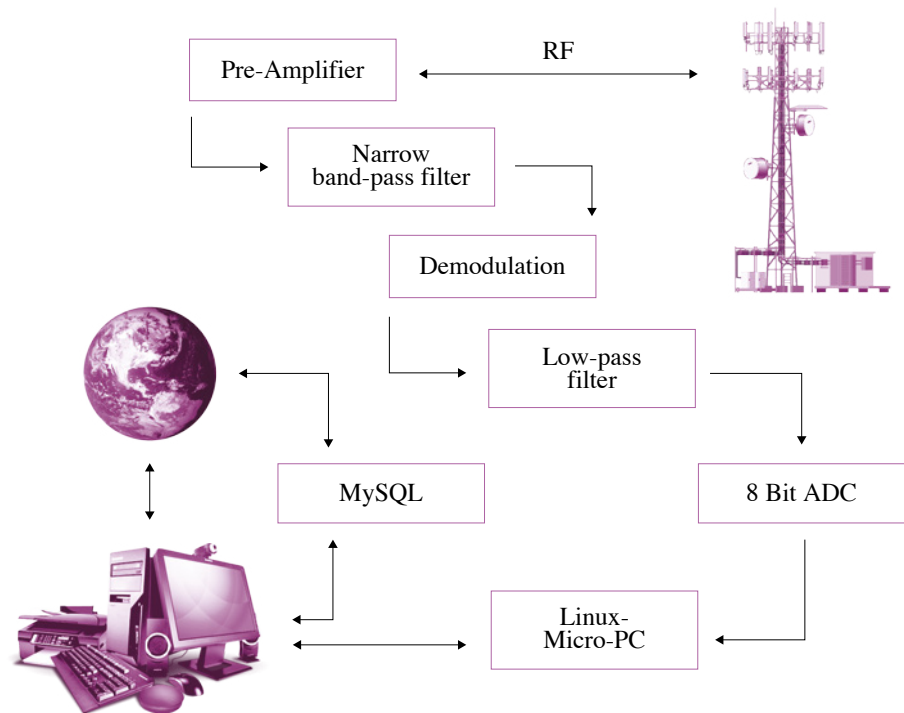


Figure 3: Sketch of a single channel VLF receiver station logic. Today's InFlaMo SDR receiver stations are broadband (multiple channel) receivers. With a SDR receiver several transmissions can be recorded simultaneously.

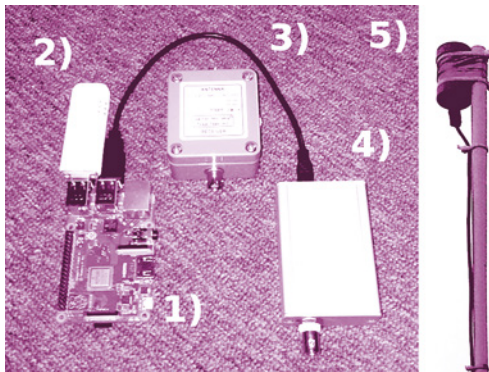


Figure 4: The PAORT Mini Whip active antenna is an electric field active antenna in a small package (Figure 4.5.) This antenna type has been selected as the ,perfect' fit for our broadband VLF SID monitor (private Communication with Mr. Roe/of Bakker). It is connected with a “Power Bridge” (Figure 4.3) to the SDR.

A typical undisturbed measurement shows typical daily variations (Figure 5), which can be divided into day and night time conditions and the sunrise and sunset variations. Here we ignore the night time conditions and determine the sunrise and sunset times utilizing the algorithm for an approximate solar position [Michalsky, J., 1988]. Other researchers utilize the center of a great circle path between the transmitter and receiver station as a location to determine sunrise and sunset times. Here we simply take the sunrise time of the western station as well as the sunset time of the eastern station. The day times are marked in figures in black. Times of enhanced noise level are mostly caused by thunderstorms on the path of the radio propagation. A sudden off level of a signal is a usual sign that the transmitter station has gone offline or maintenance was being performed.

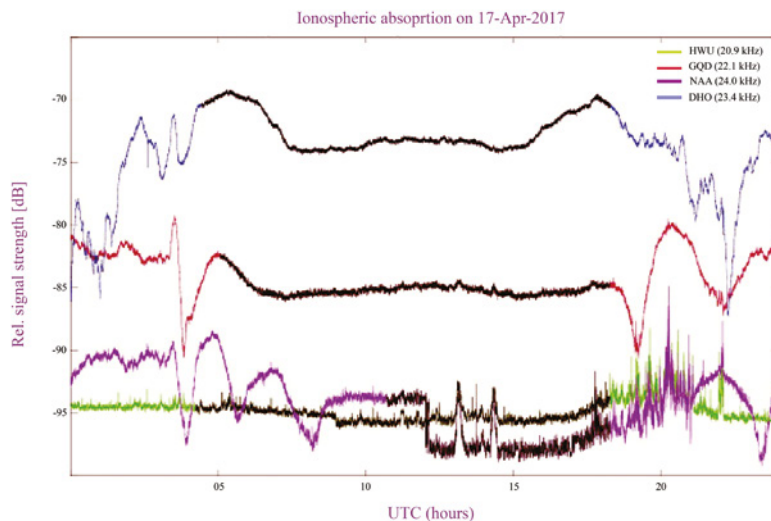


Figure 5: Example of typical quiet daily measurements of 4 different VLF transmitters.

18-Apr-2017 GOES 15 X-ray flux computed by www.InFlaMo.org

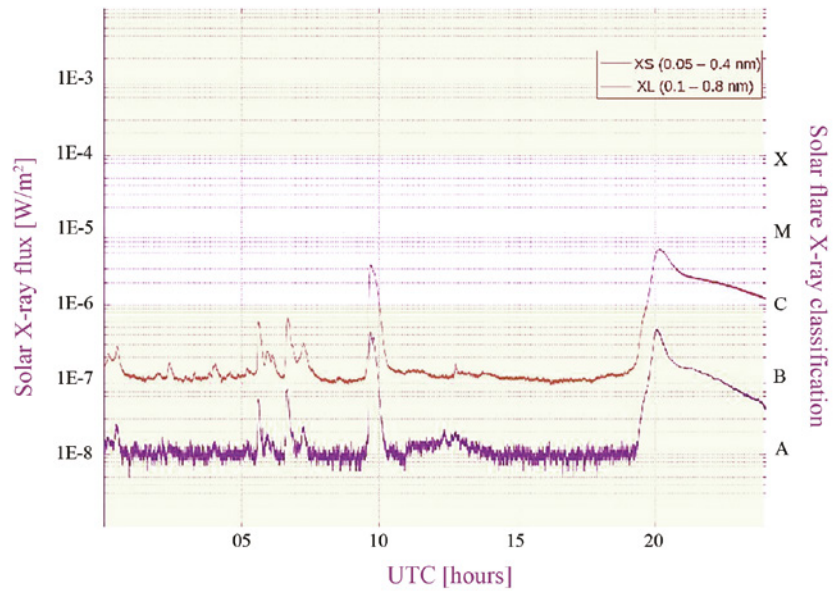


Figure 6: C2.5 solar flare shortly before 70 UTC

VLF Signal minus QDC of GQD 22.1 kHz on Apr. 17th, 2017

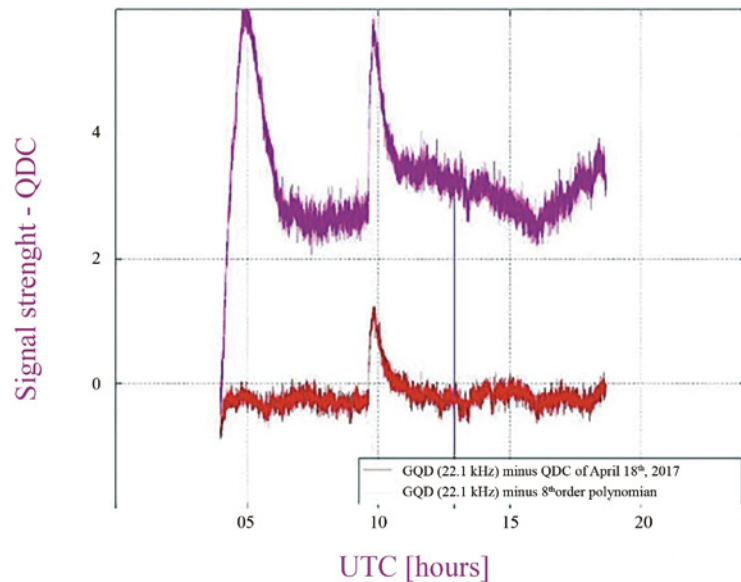


Figure 7: The VLF daytime signals subtracted with i) a polynomial 8th order and ii) with a quiet day curve (QDC) from April 17th, 2017

5. Example of an in-classroom application

The curriculum for upper secondary physics classes requires educators to introduce the phenomena of photoionization and many textbooks are utilizing the aurora as a visible example. However, the resulting appearance of various ionospheric layers can be best experienced with radio experiments.

We suggest utilizing freely available satellite data to search for solar sources, which may cause an enhancement of photo-ionization in our upper atmosphere. In our example, we choose GOES X-ray flux data from <http://www.noaa.gov>. Figure 6 shows the solar X-ray flux measured by the GOES 15 satellite on April 17th, 2017. It is not an undisturbed day. However, the ionospheric reaction will not appear as long as the solar X-ray flux is below a C class solar X-ray flare level. If the solar X-ray flux exceeds the value of an X class solar X-ray flare level, then the ionospheric reaction might behave non-linearly. Also, the C1-class solar flare at 03 UTC is not of importance to our study since it is occurring at the station's local night time.

Students at that age group have got introduced to interpolation algorithms at their maths classes. Many schools demand their students to utilize a computer algebra system (CAS) on their tablet-computers. The InFlaMo measurements provide good data to exercise polynomial fits or subtraction of data points in order to find a normalized quiet day curve (QDC). Utilizing the QDC method is obviously the more reliable approach for our example. We see that a C2.5 solar flare corresponds here to about 1.6 arbitrary units in the plot (Figure 7).

Curious students might notice that the upper ionosphere shows no reaction as long as the X-ray flux is below $1 \cdot 10^{-6}$ W/m² (C-class solar flare). In the case of an X-class solar flare, the ionosphere behavior is non-linear. Both regimes are marked yellow in the figures.

6. Conclusion

This presentation offers an exciting way to experience phenomena of physics and mathematics that could otherwise be only read from textbooks. In particular, the topics of radio wave propagation, photo-ionization, solar variation, and flares, as well as applied CAS techniques, can all be exercised in one experiment. The combined affinities of different students to each one of those topics may result in a valuable presentation at the next science fair. Educators can be granted access to the InFlaMo data since 2012 for such purpose. The InFlaMo project provides background information on upper atmosphere space physics knowledge and encourages schools, educators and citizen scientists to participate. They may become a member of the InFlaMo project and can obtain their own InFlaMo receiver station.

References

- S. Schade et al., 2010, *Fichten-Fieldday-Projekt FiFi-SDR*, Funkamateure 11, p. 1159
- E.-G. Schweppe, 2011, *Preselektor für das FiFi-SDR*, Funkamateure 10, p. 1062
- D. Kenneth, 1990. *Ionospheric Radio*. IEE Electromagnetic Waves Series #31. London, UK: Peter Peregrinus Ltd/The Institution of Electrical Engineers. pp. 316–317. ISBN 978-0-86341-186-1
- Roelof Bakker, PAORDT: The PAORDT-Mini-Whip, an active receiving antenna for 10 kHz to 20 MHz, report (private communication)
- Michalsky, J., 1988: *The Astronomical Almanac's algorithm for approximate solar position (1950-2050)*, Solar Energy 40, 227-235

Digital technologies as didactic resource for science teaching in the last year of elementary school of public schools in Brazil

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Abstract

The technological transformations in the last decades have asked the teachers a new look at how to teach and why to teach, since it is necessary that the knowledge be transformed to connect with the daily life of the students. So the school must also adapt to this new. This work aimed to verify the insertion of digital technologies in the daily life of the students of public schools of the state school system in Brazil. Four schools were chosen for the research, two of which were located in Divinópolis MG, a city in the interior of Minas Gerais, and two located in the outskirts of Greater São Paulo. In the research the students answered a questionnaire with six objective and discursive questions. From the analysis of the answers given it was concluded that more than seventy percent of the students use the smartphone as the main tool associated with digital technologies. Other options like tablets or desktop computers were little chosen. When we asked about the use of digital technologies by the teacher during science classes, there were very different answers. At school A, 30 students stated that the science teacher does not use digital technologies in their classrooms. In

school B, in the same city the result was the opposite, because all 36 students said the teachers' daily use technologies. At school C, 22 students said that they did not use technologies in their classes while at school D, only 17 students made this statement.

Keywords

Digital technologies; Teaching; Science; Traditional teaching methodology

1. Introduction

Technologies, especially digital ones, invade people's daily lives and can provide new perspectives, broadening their vision on various topics, including education. It is important to emphasise the presence of digital technologies in the school environment, since these aim to support a new teaching pattern, in other words, technologies must support students in their learning, constituting an important educational resource.

The idea of the use of digital technologies in the classroom, seeks to arouse the interest of the student and through this interest expand their learning. As argued by Moreira (2005), in order for the student to achieve meaningful learning, he should initially want to learn and the initiative of this interest must begin with the practice of the teacher in the classroom. Often the link between scientific concepts and everyday aspects of students is linked to the teaching practice of the teacher.

The use of digital technologies that allow a differentiated class, through the use of experimental contributions or computational simulations, can provide the student with a different view of scientific concepts, facilitating understanding and learning. The use of digital technologies in the school environment has promoted changes contributing to access to information, given the ease of access to the web mainly by the use of smartphones. It is observed that even today many teachers or educational institutions prefer to prohibit the use of these digital technologies in the classroom instead of exploiting them in favor of students' learning. As these digital technologies are immersed in the students' daily life, it can be assumed that their use in school can contribute to the meaningful learning of the concepts worked.

According to Pinheiro and Rodrigues (2012), the smartphone is a powerful pedagogical tool, because it concentrates several media, contributing to the development of communicative skills to the students. The teacher should have the function of directing and coordinating the use of these digital technologies in the classroom, since many students do not have the maturity to discern when it is appropriate to use these tools.

This work aimed to analyse the conception of a sample of 130 students from public schools in two Brazilian states on the use and learning of science concepts using resources related to digital technologies.

2. Significant Learning and Mechanical Learning

Meaningful learning is the process by which a new concept relates in a non-arbitrary and substantive way to the learner's cognitive structure Moreira (2005). Because it is an interaction, the previous concepts are transformed, becoming more elaborate, and the new concepts acquire meanings. In this way, prior knowledge helps in the incorporation and understanding of new knowledge, when they are based on relevant concepts, the so-called subsumption concepts.

Moreira (2005), state that in order to learn meaningfully, the learner has to express a willingness to relate the meanings he draws from potentially meaningful educational materials to his non-literal and non-arbitrary cognitive structure.

Second Braathen (2012): Mechanical learning occurs with the incorporation of new knowledge in an arbitrary way, that is, the student needs to learn without understanding what is involved or understand the meaning of why.

In the daily routine of school it is realized that it is perfectly possible to occur mechanical learning and meaningful learning in the same study session or in the same classroom. This justifies how important it is for the teacher to work several teaching methodologies, using various educational resources, so that he will be able to develop different learning with the students.

3. Digital Technologies and Teaching Science Learning

As can be seen, digital technologies are increasingly inserted in the daily lives of students and teachers. The blackboard, chalk and notebook are no longer the only available materials that can be used as teaching methods today.

Despite the availability of new technologies for teaching, there are still major difficulties in introducing these new teaching methods, mainly involving digital technologies.

Second Junquer e Cortez (2010): Young people today have found in the use of smartphones an area of independence of the adult world, which accelerates a supposed majority, regardless of their social class and the variety of models of this support, since all social classes carry cell phones, from the simplest to the most sophisticated and technologically advanced. The justified purpose for its great use is that the contact between parents and children requires more care, attention and closeness in daily life. And most young people say that they can not stop using this technology communication tool, since their use is the best way to have and keep friends with whom they establish relationships that are characterized by the exchange of advice, ideas and information of the moment they are living. They also use as artifice for the activities of each age group, since they guard against any interference from adults.

The use of different digital technologies such as simulations, PowerPoint presentations, educational games, YouTube videos and the applications themselves, when properly used, allow students to have contact with other forms of language, and also provide a teaching to these new generations, who from the outset present intimacy and mastery over these new digital technological resources.

4. Methodological Procedures

The research with the schools was carried out from the application of a questionnaire with six questions, being objective and discursive. Four state public schools participated in the study, two of which were located in the city of Divinópolis, in the state of Minas Gerais, and were named A (32 students) and B (36 students) and two schools located in the outskirts of Greater São Paulo, called C (31 students) and D (31 students).

A total of 130 students were studied, with an average age between 13 and 14 years old, all of them attending the last year of Elementary School. A study of the data was carried out based on the techniques of content analysis of Bardin (1994), by categorization of responses and grouping by similarities.

5. Results and Discussions

In this section some of the answers given to the survey questionnaire will be presented and discussed.

The question 1, asked the students about which computer equipment they used most in their daily lives. Table 1 gives an outline of the answers given to this question.

Table 1: Quantitative responses to the first question.

| Schools | Smart-phone | Notebook | Desktop computer | Smartphone and Notebook | Others | Does not have |
|---------|-------------|----------|------------------|-------------------------|--------|---------------|
| A | 20 | 0 | 4 | 2 | 6 | 0 |
| B | 30 | 1 | 3 | 0 | 2 | 0 |
| C | 21 | 5 | 2 | 1 | 2 | 0 |
| D | 22 | 5 | 2 | 1 | 0 | 1 |

It was noticed that the smartphone option was the most chosen by the students, which was already expected, after all, today students are very connected and even dependent on this device. It was found that among 130 students surveyed only one said that he did not have access.

The question 2, presented nine options related to students' frequent or non-use of digital technologies to perform day-to-day tasks. Students were asked to rate the options between "I do not use"; "Little use"; "I quite use". The Table 2 presents the nine items available for students' choice of use or not.

Table 2: Items in question 2 for classifying students as to their use or not.

| Options for answers to question 2 | |
|-----------------------------------|---|
| 1 | I use the computer only to process texts |
| 2 | Social network, Facebook, Instagram, Games, Twitter |
| 3 | Educational software / CD-ROM |
| 4 | School works with computer |
| 5 | Video lessons on YouTube |
| 6 | Virtual libraries |

- 7 Educational apps for smartphone

- 8 Virtual simulations of images and animations related to Sciences

- 9 School Informatics Laboratory

Figures 1 – 4 respectively illustrate the graphs representing the answers given to question 2, by school. The horizontal columns in the graphs represent the students' choice of the items shown in Table 2.

It was observed that the four graphs presented in the previous Figures presented values, where the number of alternatives chosen did not coincide with the total number of students studied per school. This can be justified by the questionnaire model used, where the proposed question is multiple choice, allowing students not to answer it or even choose more than one item among the response options. It was observed that the graphs of Figures 1 – 4 presented values greater or less than the number of students per school, participants of the research.

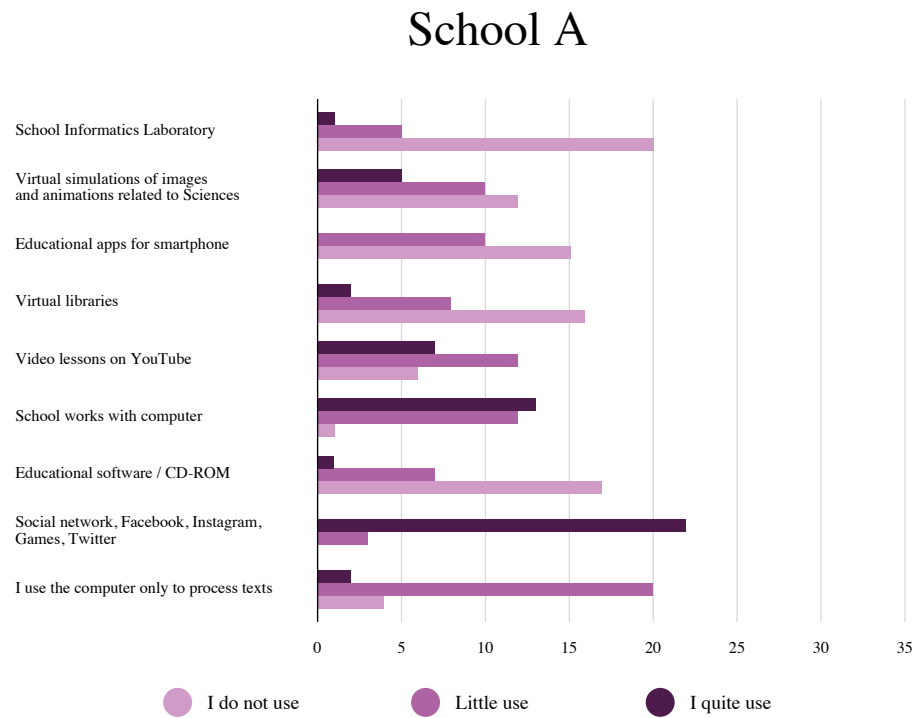


Figure 1: Graph with the answers from school A.

School B

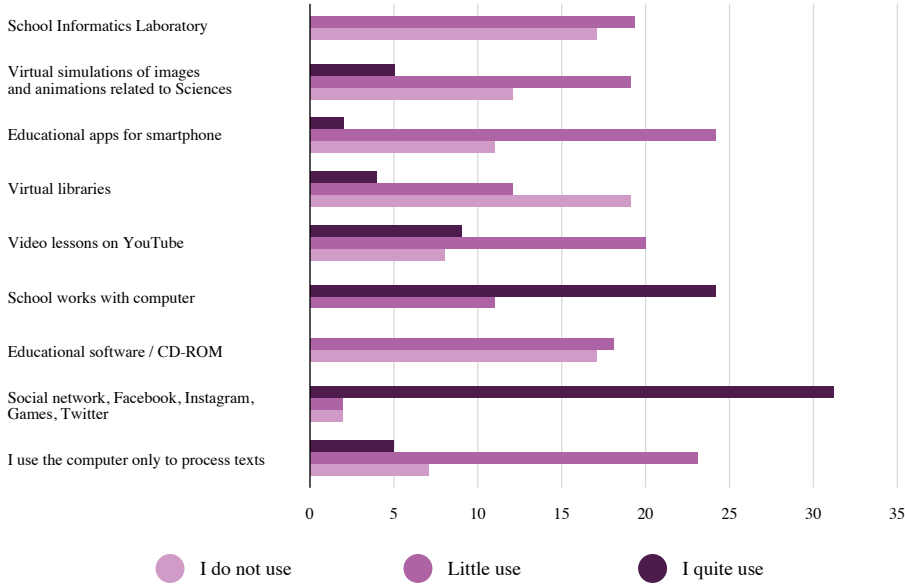


Figure 2: Graph with the answers from school B.

School C

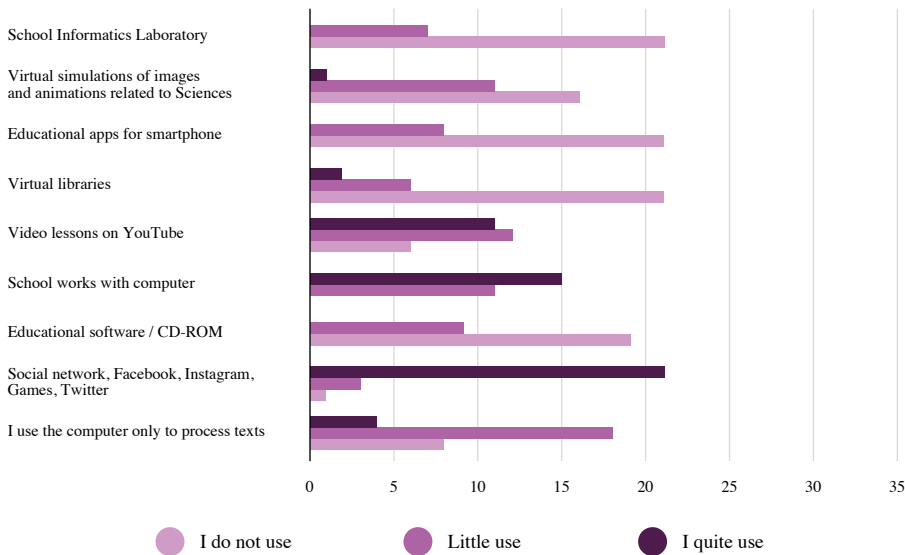


Figure 3: Graph with the answers of the school C.

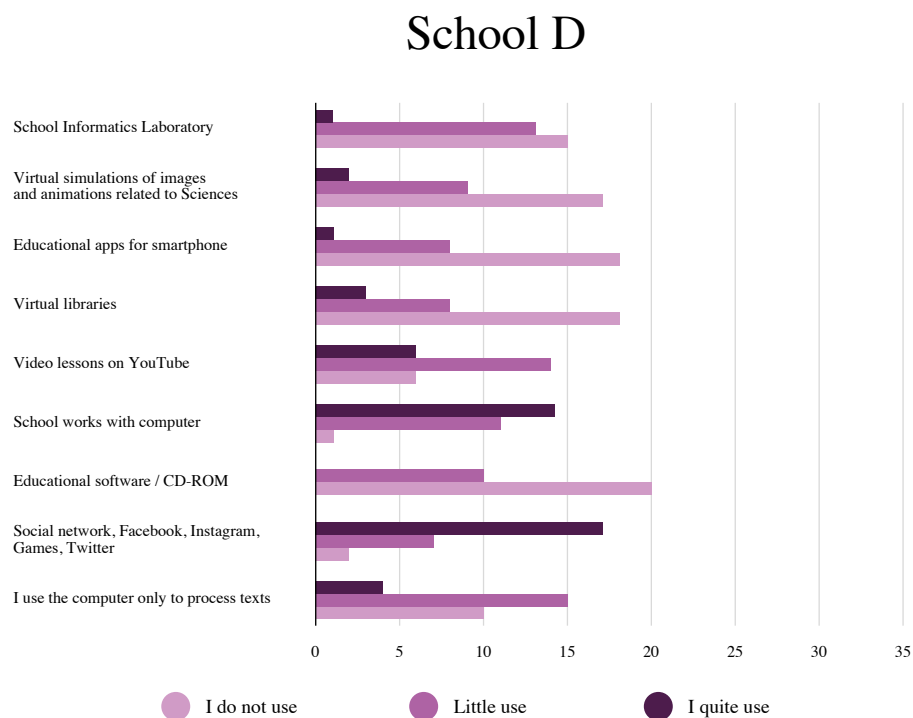


Figure 4: Graph with the answers of the school D.

In relation to the term “quite use”, the graphs of the four schools, represented in Figures 1 – 4, showed the predominance of items 2, 4 and 5 (Table 2) that refer to social networks, computer on school assignments and video lessons on YouTube. There was more emphasis on item 2, which includes the use of social networks and Facebook, which is the most chosen in the four schools. It was noticed that even in different schools, located in different regions of Brazil, there was a predominance of this choice since the vast majority of students have smartphones, which facilitates access to social networks and Facebook.

In question 6, students were asked if they had Astronomy classes in Elementary School and if during these classes, teachers used digital technologies, such as simulations, videos and smartphone applications to exemplify and assist in the teaching of such content.

At school A, 27 students answered “no”, most of whom justified that they had not studied Astronomy or did not remember. Only five students answered “yes” to this question. In school B there were very varied answers and these are represented in Table 3. It is clear that in this school the students had little contact with the content of Astronomy and the teachers, by the students’ reports, did not use digital technologies in teaching. At school C the answers were more homogeneous and 14 students answered “no” and 14 students answered “yes”. Only three students did not answer this question. At school D, 27 students answered “no”, one answered “yes” and three did not answer the question.

It was observed that in the four schools most of the students answered “no”, indicating that they did not study Astronomy properly in Elementary School or that their teacher did not work this content using digital technologies linked to education.

Table 3: Representation of the answers given by the students of the school B.

| Answers Given | Quantitative of students who answered |
|---|---------------------------------------|
| No | 19 |
| Do not remember | 5 |
| Others (“Never used anything”, “No textbook”) | 4 |
| Yes | 8 |

6. Conclusions

Most of the 130 students reported having access to digital technologies, as seen in item 2 presented in Table 2 with the use and access to social networks and Facebook, but it is noticed that there is still resistance in the schools to use resources linked to digital technologies for teaching. It was observed in the graphs of question 2, represented in Figures 1 – 4 that most schools do not use or have a computer lab. This shows a lag in the education system where many schools fail to provide minimal support to students for use and access to the web.

In the four schools, the question that asked students if they had studied Astronomy in Elementary School and if the teacher had used some resource tied to digital technologies, had a high index of “no” answers.

This was a worrying fact since the contents of Astronomy second the National Curriculum Parameters, Brazil (2002), should be worked on in Elementary School.

References

- Bardin, L. Content Analysis. Lisbon: Issues Seventy, 1994.
- Braathen; P. C. Mechanical learning and significant learning in the teaching/learning process of Chemistry. Magazine axis. No 1. Vol. 1. Dep. Of Chemistry. UFV. 2012.
- Brasil, Secretariat of fundamental education. Guidelines for the PCN of Elementary School: National Curricular Parameters: Introduction to the national curricular parameters / Secretariat of Fundamental Education. – Brasilia: MEC / SEF, 2002.
- Junquer, A.C.L.; Cortez, E.A.S. The different media and the use of the cell phone in the classroom. Workshop held at the V National Seminar the teacher and the newspaper reading. Unicamp, 2010. Available at: <<http://ltp.emnuvens.com.br/ltp/article/viewFile/58/57>>. Accessed on: September 15, 2017.
- Moreira, M. A. Significant critical learning. Porto Alegre: Institute of Physics of UFRGS. 2005. Available at: <<http://www.if.ufrgs.br/~moreira/apsigcritport.pdf>> Accessed on: 09/25/2017.
- Pinheiro, R. C.; Rodrigues, M. L. The use of cellular as a pedagogical resource in Portuguese language classes. Philologus Magazine. V. 18, N. 52, P. 119-128, Jan.-Apr., 2012.

Practices of outreach in Astrobiology

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Abstract

Interest in the existence of aliens has always been high. A large number of exoplanets have been found, and it is now an age when life in the Universe can be scientifically studied. “Astrobiology” is a new research field that search for places in the Universe that can accommodate life, in addition the existence of life itself, and discuss the origin and the evolution of life without solely on the Earth. It is not only astronomy and biology, it is a multidisciplinary research field such as planetary science, Earth science, molecular science, life science and engineering. While many spacecrafts and various aliens are depicted in science fiction movies, it is not well-known actual astrobiology research. I will here introduce activities to install in society the research field of “Astrobiology” in Japan.

1. Introduction

As a result of developments in extrasolar planet observations, astrobiology research to explore “Life in the Universe” and uncover its mysteries has become a pressing subject. Astrobiology Center (ABC) established in National Institutes of Natural Sciences (NINS) in Japan in 2015. ABC advances this field by combining disciplines, promoting research into extrasolar planets and life both outside and within the Solar System, and develops observational instruments for these purposes.

Our center consists of the following project offices.

- Exo-Planet Search Project Office
Habitable Planet search with Subaru and TMT and space telescopes.
- Exo-Life Search Project Office
Atmosphere analysis and biosignature confirmation on habitable planets.
- Astrobiology Instrument Project Office
Instrument development for 2nd Earths on TMT and future space telescopes.

ABC researchers promote astrobiology research, exoplanet search, biosignature on the exoplanet and instrument development, in each project offices. However, we have less than 20 researches (as of 2019) and astrobiology field is quite wide. Therefore, other astrobiology related researchers promote on a collaborate basis.

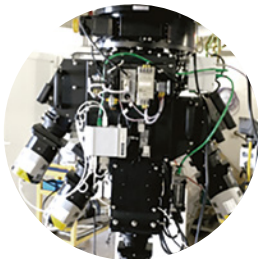


Fig. 1: 1.5m telescope (TCS) in Tenerife, Canary Islands (upper) and 4 color simultaneous camera MuSCAT2, for search exoplanets (lower)

2. Activities

ABC main activities are bellows,

- Grants-in-aid for astrobiology research
- Cooperation with foreign astrobiology institutes
- Inter-university cooperation for instrument development (Fig. 1,2)
- International workshops (Fig. 3),
- Invitation of foreign researchers and development of young researchers (Fig. 4).

3. Outreaches

3.1 ABC website

Press releases and web releases were announced on ABC website since 2015. Between 2015 to 2019 Sep, 24 research has been presented on our website (include collaborative research). In 2019, the website renewed [1]. Our releases include astronomical and biological topics.

3.2 Public talks

We had many Exoplanet and/or Astrobiology related public talks in various kind event, i.e. science café, star gazing party, planetariums event and international event (Fig. 5).

In some case, such public talk includes Astronomy part and Biology part. However, Astronomy and Biology are quite different discipline for the audience (and also speaker). Therefore, development of effective communication method for Astrobiology is needed.

3.3 Workshop/Event for children

- **Draw your Aliens:** Many researchers feel difficulties to the SHAPE of aliens. On the other hand, children have free imagination. We try to input some scientific background, such as habitable zone, planet size, biological evolution and so on, to children, then draw some of their original aliens in workshops (Fig.6).
- **NAZO-TOKI (solve riddles) events:** “NAZO-TOKI” workshop is an Active learning type science outreach and communication method [2]. This workshop can set some riddles related astronomy and biology respectively. Participants think about astronomy and biology, then solve the next riddles (Fig.7). Such process is similar to Astrobiology research itself.

1. Future works in ABC outreach

- **Increasing Astrobiology related exhibits and novelties:** Comparing with Astronomy and Biology, the number of astrobiological exhibits are still quite small. It needs to seek some interesting exhibits for Astrobiology. ABC is still a new center and only have a few novelty goods.

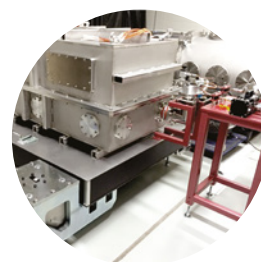


Fig. 2: New instrument for exoplanet exploration, Infrared Doppler (IRD), which is mounted on Subaru telescope in Mt Mauna kea, Hawaii.



Fig. 3: Life in the Universe workshop. In order to present latest results of ABC grants-in-aid programs to Astrobiology community, we hold the workshop every year.



Fig. 4: Young researcher workshop. We hold some workshop for development of young researchers.



Fig. 5: Thai-Japanese Astronomy event 2016 (NARIT). Most participants are junior/high school students in Thailand.



Fig. 6: Drawing event in open campus. Children drew their alien and made a phylogenetic tree of an exoplanet.



Fig. 7: NAZO-TOKI event. Children try to solve some astrobiology related riddles and open a treasure chest. When done, they get some treasure.

- **NAZO-TOKI event:** This is new approach for science outreach/communication. It is similar to “Quiz rally” but the riddles level is relatively high. These riddles features not only scientific information but also need action and thinking. Typically, these answers are important hints for the next or last riddle. It is quite difficult to create the riddles, but this event can be expected to be good tools for active learning and connection of Astronomy and Biology.

Through these events and public talks, we will convey actual astrobiology research.

References

- Astrobiology homepage: <http://abc-nins.jp>
- N. Kusakabe, *Communicating Astronomy with the Public Conference 2018 Proceedings*, p.143, 2018

Development of a sustainable system for education through an astronomy club

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Abstract

An astronomy club in Chiyoda Ward Kudan Secondary School holds stargazing events for elementary school students once a month. At this event, though astronomers give a lecture at first, later activities such as a planisphere workshop, stargazing with telescopes are all performed by the students of the astronomy club. The astronomers taught the students about astronomy when we started to hold the event. However, now they are studying independently and deepening their knowledge. Their club activities have been an opportunity for the students to study independently. Recently, some of the students who participated in the stargazing events joined the astronomy club. Moreover, graduates from Kudan secondary school have been teaching to the students. They have improved their teaching skills through astronomy club activities. We succeeded in establishing a cycle to educate the next generation through these stargazing events.

1. Introduction

Kudan high school has a 15 cm refractive telescope inside a dome on the top of a school building, and an astronomy club at the high school had lasted about 80 years[1]. The high school integrated with Kudan junior high school and became Kudan Secondary School in 2006[2]. At that time, there were no school geology teachers and no person who could use the telescope in the school. Therefore, the astronomy club disappeared in 2009.

However, some school science teachers of the Kudan secondary school wanted to use the telescope to organize stargazing events for the public, especially local elementary school children. The school teachers requested the cooperation with some astronomers and some graduates of the Kudan high school astronomy club. Moreover, graduates of the Kudan high school wanted to revive the astronomy club.



Fig. 1: 15 cm refracted telescope of the Kudan.

Therefore, the teachers, the graduates, and some astronomers cooperated to design the stargazing events at Kudan secondary school for local children and to revive the astronomy club.

Table 1: The contents of the stargazing events.

| | | |
|------------------------|--------|--|
| Opening & Lecture | 30 min | Astronomers give a lecture for children. |
| Making a planisphere | 30 min | The students teach the children how to make a star wheel. |
| Stargazing at the roof | 25 min | The children gaze stars with 4-5 small telescopes. The students teach the children how to use the telescope. |
| Stargazing at the dome | 25 min | Stargazing with the 15 cm refracted telescope. |
| Closing | 10 min | The children write an essay about the stargazing event and get a certificate of completion. |

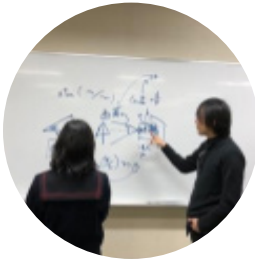


Fig. 3: Presentations at the junior sessions of the Astronomical Society of Japan in 2018 and 2019.

2. Method

2.1 Pre-Stargazing Event for the students

At first, the Pre-stargazing event was held for the Kudan secondary school students in October 2009, to train staff of the stargazing events for the elementary school students[3]. There was not only an observation of stars but also lectures on how to use the telescope and astronomical simulation software “Mitaka”.

2.1 Stargazing Event for the local children

In November 2009, we started the stargazing events for the local children. In order to call for participants, we announced this event using posters and homepages. Table 1 shows the contents of the event. The contents of the event were not only stargazing with the telescope but also lectures on how to use the telescope and lectures of astronomy using the astronomical simulation software. Because of this, we limited ten families of the number of participants in each event.

From 2009 to March 2019, we held 82 stargazing events for the local children. Figure 2 shows the total number of participants (dark purple line) and the total number of applicants (purple line) each fiscal year. The total number of applicants until March 2019 is 6211 for capacity 820.

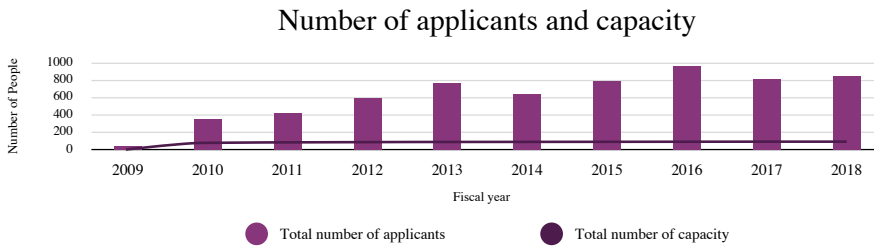


Figure 2: The total number of participants (dark purple line) and the total number of applicants (purple line) each fiscal year.

3. Results and Discussion

Through the stargazing events, the “New” astronomy club was established at the Kudan Secondary School in April 2010.

The astronomers taught the students about astronomy when we started to hold the event. However, now they are studying independently and deepening their knowledge. Their club activities have been an opportunity for the students to study independently. They also have interested in astronomical research. Under the guidance of the astronomers, they have advanced their research and made presentations at the junior session of the Astronomical Society of Japan in 2018 and 2019 [4][5]. Figure 3 shows presentations at the junior session of the Astronomical Society of Japan in 2018 and 2019.

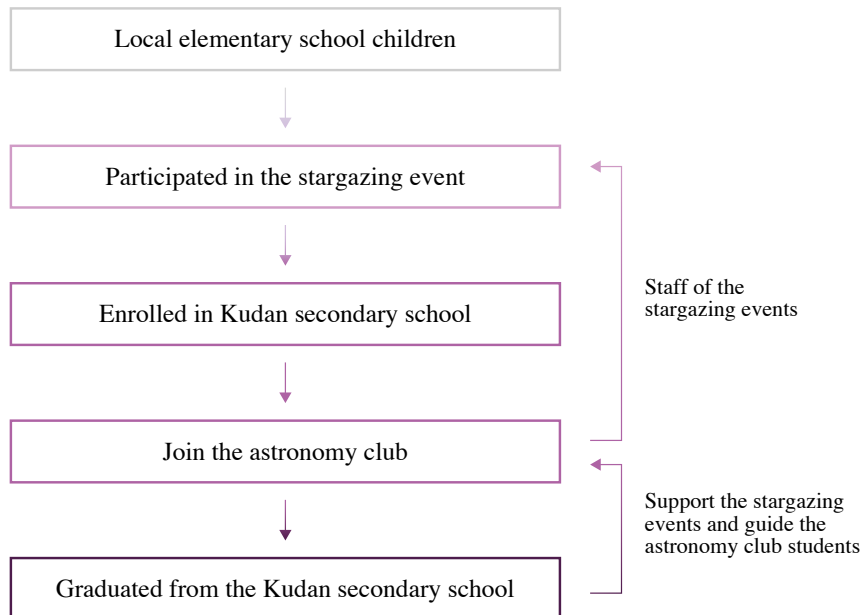


Figure 4: Conceptual diagram of the cycle to educate the next generation.

Recently, some of the students who participated in the stargazing events joined the astronomy club. Moreover, graduates from the Kudan secondary school have been supporting and teaching to the students. The graduates have improved their teaching skills through astronomy club activities. Figure 4 shows conceptual diagram of the cycle to educate the next generation. We succeeded in establishing a cycle to educate the next generation through these stargazing events. Developing such activities as a sustainable system of astronomy education will be an issue in the future.

4. Summary

We designed the stargazing events at Kudan secondary school for local elementary school children, and to revive the astronomy club. From 2009 to March 2019, we held 82 stargazing events for the local children. The astronomy club activities have been an opportunity for the students to study independently.

Some of the students who participated in the stargazing events joined the astronomy club. Moreover, graduates from the Kudan secondary school have been teaching to the students. They have improved their teaching skills through astronomy club activities. We succeeded in establishing a cycle to educate the next generation through these stargazing events. Developing such activities as a sustainable system of astronomy education will be an issue in the future.

Acknowledgement

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References

- [1] Isseikai, Astronomy club for 80 years “Uchu”, 2009
- [2] Kudan secondary school homepage: <http://www.kudan.ed.jp>
- [3] S. K. Kawagoe, N. Kusakabe and S. Nakamura, Communicating Astronomy with the Public Conference 2018 Proceedings, p.187, 2018
- [4] 20th junior session of the Astronomical Society of Japan Abstracts, 40T, p.53, 2018
- [5] 21st junior session of the Astronomical Society of Japan Abstracts, 10T, p.15, 2019

Session

Abstracts

III

Session III.I

*Presentation/
Workshop Abstracts*

Day I

Keynote 1 – AER Pathways: Recent Research and Future Directions

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Astronomy education research (AER) offers insights into a variety of topics, such as teaching and learning across formal and informal settings, professional development for teachers and faculty, attitudes and beliefs about astronomy, and public understanding of astronomy topics. The field has broadened dramatically from being focused on identification of naïve conceptions and the evaluation of teaching strategies. Collaborations across many settings and areas of expertise are allowing astronomy education researchers to push boundaries into new areas of research. Likewise, publication venues vary widely, providing both opportunities and challenges to researchers who want to share their research with the larger community. Future directions for AER include but are not limited to improved methodological designs, such as the use of mixed methods or robust quantitative analyses; longitudinal studies; and new topics such as spatial thinking in astronomy, motivation and related constructs, and the use of visualizations and simulations.

Astronomical Midlands: Engaging Rural Communities in Ireland with Radio Astronomy

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The Irish Midlands has a rich heritage in astronomy, a fact that is not well known in this region of higher than average unemployment and low uptake of post-secondary education. We have therefore embarked on a regional engagement project – the Astronomical Midlands (AstroLands) – which uses the recently constructed Irish Low Frequency Array (I-LOFAR; lofar.ie) radio telescope and I-LOFAR Education Centre at Birr Castle in the Irish Midlands to connect with students, teachers and members of the public in local, rural communities in the Midlands. In this presentation, we will describe our three key initiatives: Space4Exploration: Developing an engaging, inspirational, and multi-use exhibition space in the I-LOFAR Education Centre; Space4Students: Day-long and week-long workshops and camps at the I-LOFAR Education Centre to run during school terms and holidays for students aged 10 to 14; Space4Teachers: Create and run Continuous Professional Development workshops for primary and secondary school teachers based around the Irish National Junior Certificate (12-15 year olds) theme of Earth and Space. With these programmes our ambition is to inspire and support teachers, students and the general public to engage with the science, engineering and radio astronomy of LOFAR.

Workshop – Technology and Student Engagement – How to increase (or decrease) Student Learning in classrooms and planetariums

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I would like to present key results from the Discipline-Based Education Research (DBER) Group at the Univ. of Colorado, the world's leading group researching college science teaching. Our PHeT applets (phet.colorado.edu) have been used 360 million times! I just finished an invited AIP review article, "Technology and Engagement in the University Classroom" (in press) and I would talk about: 1. Those who teach astronomy overestimate learning. 2. Student engagement is critical. 3. How

technology such as “clickers” and simple methods such as colored cards can significantly increase learning (with extensive data!) 4. The circumstances under which technology REDUCES student learning. 5. The key discovery that many student misconceptions repeat year after year, and so can be addressed in particular, effective, inexpensive ways 6. How to bring more active learning to planetarium settings or to science-teaching videos. 7. If desired, my latest research on how texting during class influences student behavior and grades, and what to do about that.

Workshop – Examining IBSE-type Activities in Astronomy

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I will present a range of activities, many in the IBSE format, which use real astronomical data, allowing students to explore datasets on objects such as exoplanets, open clusters and supernovae. These activities encourage students to share and reflect upon their results with each other.

The Use of an Authentic Research Experience in Astronomy to Teach the Process of Science

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“Research-Based Science Education” (RBSE) is an established instructional model that integrates scientific research with education by giving introductory-level undergraduate astronomy students an opportunity to do authentic research with real data. RBSE is a course-based undergraduate research experience (CURE) in astronomy. Its goals are threefold: (1) to teach that science is a process of discovery, not just a body of knowledge, (2) to improve attitudes towards science and STEM careers, and (3) to develop critical thinking, teamwork and goal-driven work skills that are important in any career path. The RBSE curriculum currently consists of five authentic research projects in astronomy: recovery observations of asteroids, searching for classical novae in M31, studying semi-regular variable stars, identifying active galaxies in spectroscopic surveys, and searching for distant galaxies in imaging surveys. Each project uses real astronomical data from professional observatories to investigate authentic research questions for which the answers are not known. In other words, in order to learn science, students are given the opportunity to actually do science. The results of RBSE student research have been submitted to scientific databases, presented at professional conferences, and published in refereed journals. As part of my talk I will present our results on student gains from participating in the RBSE program. I will also discuss the future of CUREs in astronomy, particularly how they will be able to use data from large surveys such as LSST.

Are teachers aware of students’ conceptions in astronomy? A qualitative analysis in Belgium

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Research on astronomy education shows that secondary school students often have incorrect ideas about astronomical concepts. Teachers therefore have to implement strategies in their lessons in order to change and refine the students’ mental models. This research focuses on the level of teachers’ awareness of these student ideas and on the possible strategies they use in class. To gain insight in both, we used focus group interviews with secondary school teachers and semi-structured interviews with teacher managers. Our findings suggest that the level of awareness about student difficulties and misconceptions varies considerably among the teachers and teacher managers. Some mental models, for example the distance model, are known by all teachers, whereas others are not known at all. Even though teachers acknowledge the importance of students’ preconceptions in general, they have difficulties using the students’ prior knowledge in an effective way in their teaching practice. According to the teachers, this is mainly due to a lack of time

and to difficulties experienced with differentiation. Awareness on misconceptions and student difficulties might therefore grow by paying enough attention to it in preservice teacher programs and by organizing professional development activities.

Astronomy Education beyond borders

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After the launch in 2014 by IAU/OAD, astroEDU, the platform for high-quality, peer-reviewed astronomy education activities is becoming a standard resource in education. The Italian astroEDU site was launched in September 2017 when astroEDU/it became its first non-English version. While having a site in the local language is obviously useful, there are a number of issues that need to be addressed, both on the practical and the theoretical side. A few examples include:

- how to adapt/include the different curricula in different countries;
- how to stimulate participation especially from the teacher side;
- how to maintain copies of the same document in different languages;
- how to assign DOIs of translated text.

We suggest to meet with all the interested participants to discuss potential and real issues, on the site in general and on the translations in particular.

Workshop – From STEM to STEAM

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As part of ESERO Austria, two STEAM workshops were developed for secondary school pupils. “Space Matters” deals with intelligent materials, programmable materials that will play a major role in space travel in the future. “Worldviews – Of scientific observation and creative (re)interpretation” offers an access to the creative use of satellite images up to the creation of one’s own images and their transmission via cyanotopy. While STEAM offers often address teachers of classical STEM subjects (chemistry, physics, mathematics, etc.), these Workshops specifically addresses teachers of creative subjects. Applied in class, the focus is on networked and creative thinking and do-it-yourself. Students who are less interested in STEM subjects will be opened an access to STEM topics. This workshop also offers teachers the opportunity to exchange ideas with other subjects, making cross-curricular teaching appealing.

<https://ars.electronica.art/esero/de/space-matters-zukunftsmaterialien-im-gestalterischen-unterricht/>

<https://ars.electronica.art/esero/de/weltbilder-von-wissenschaftlicher-betrachtung-und-kreativer-umdeutung/>

Workshop – Big Ideas in Astronomy: A Proposed Definition of Astronomy Literacy

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What does it mean for a citizen to be “literate” in astronomy? Those members of the International Astronomical Union (IAU) who are active in public outreach have practical experience of the kinds of astronomical knowledge commonly held by the general public. Until recently, however, there had not been a systematic evaluation and a clear definition of what astronomical literacy means. Now, the “Big Ideas in Astronomy: A Proposed Definition of Astronomy Literacy” booklet has been released with the aim of clarifying these ideas. It is intended for use by the astronomy education and outreach community, and within a process of community consultation. The booklet is the culmination of years of debate and discussion over the essential things that an astronomically literate person should know. “Big Ideas in Astronomy” is intended to be an evolving resource for the community to contribute to and draw from in working towards their goals. The booklet will benefit wider society by informing nations and states about what constitutes astronomical knowledge for their curricula. It also provides a framework for policy suggestions for governments, teacher training institutes and programs, and a set of guidelines for curriculum development and assessment tools. In this workshop we will present the Big Ideas, and involve participants to contribute their ideas towards next steps for the project.

An Investigation Of Student’s Conceptual Understanding Of Cosmology

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In this study, we analyse high school students’ conceptual understanding of cosmology. Drawing from previous studies in astronomy education and accepted scientific models of the Universe, we identified seven dimensions that we deemed as important

to understand key concepts of cosmology: (i) age of the Universe and its determination, (ii) Big Bang, (iii) expansion and future evolution, (iv) how temperature and composition change with time, (v) celestial objects and their relationship, (vi) black holes and dark matter, (vii) time and distance scales. Then, we designed a questionnaire featuring nineteen open-ended questions. Content validity was checked with three professional astrophysicists. The questionnaire was administered to 411 high school students (17 to 19-year-old) who had already received curricular instruction about cosmology in Earth Sciences and Physics classes. Students' responses to questions related to dimensions (i-iv) were first categorized using a grounded approach and then combined through cluster analysis to identify common patterns of students' understanding. Data suggest that: (a) only 15% of students are aware of any experimental evidence to support the Big Bang or the estimate of Universe age; (b) about two-thirds of the students held alternative or non-scientific views about Universe expansion and evolution; (c) about half of the sample had no idea about how Universe temperature changed in time. Findings raise the question of how to foster a sound conceptual understanding of Cosmology. To address this issue, we are developing a teaching-learning sequence focused on the identified dimensions.

Learning about the multidimensional Universe – challenges and possibilities

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When students enter the discipline of astronomy, they will face numerous challenges. Not only do they need to use all disciplinary knowledge for physics and mathematics in new ways, they also need to learn the disciplinary ways of knowing in astronomy. These differs from physics and mathematics and one can describe this as learning a new language—astronomy. Theoretically, this is referred to as Social Semiotics and here all communication within a discipline is described by the disciplinary semiotic resources that have been developed by the discipline over extended time periods. In this talk, I will present social semiotics in astronomy and in particular the concept of Disciplinary Discernment and how this is important to consider when teaching and learning about the multidimensional Universe. Results from a recent empirical study will be used to exemplify disciplinary discernment of multidimensionality, and I will discuss multidimensional semiotic resources potentials for teaching and learning astronomy.

Knowledge of astronomical scale: measurement and evaluation

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Having an appreciation for astronomical scale is significant for understanding the foundations of astronomy. However, a key challenge in developing this understanding is the lack of direct ways to acquire this knowledge. Personal experience may even be detrimental, given that our direct experience is of the Earth as something very large, whereas stars are tiny pinpricks of light. As a first step to address this issue, it is necessary to assess people's knowledge of astronomical scale to identify common misconceptions and evaluate the effectiveness of educational interventions. However, no instruments so far have enabled evaluation of people's knowledge of astronomical scale for multiple objects. Previous instruments have generally only included a few questions about scale—mostly through multiple choice—limiting the number of objects simultaneously probed to three and often not probing all possible rankings. To measure people's knowledge of astronomical scale, we developed an instrument that allows for easy collection, analysis and presentation of data ranking multiple astronomical objects (we included up to ten objects). I will present this instrument and the results from three different samples: middle school students (N = 922), pre-service science teachers (N = 41) and visitors to a public guided astronomy night viewing tour (N > 500). For all samples, data before and after astronomy instruction was collected, revealing dominant misconceptions in rankings in astronomical scale and preliminary results on the effects of various types of instruction.

Workshop – From basic scientific knowledge to high tech for a penny – workshops at ESO Supernova

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The European Southern Observatory (ESO) visitor centre and planetarium, ESO Supernova, offers inquiry based workshops for school pupils as part of its education programme and for teachers and educators as part of teacher trainings. These workshops cover curriculum relevant scientific topics while their depths range from basic knowledge to recent astronomical discoveries and technological developments. They are designed in a way to be cost effective in construction and operation. Nearly all materials are daily life materials that can be purchased in a department store or a DIY market. This allows students to build their own workshop and continue their research at home whereas schools with lower budget have the possibility to build their own workshop kits. In addition, the design of the workshops has given ESO Fellows the possibility to take portable versions of the workshops to schools in other countries, engage with pupils and students and bring recent astronomical discoveries into the classroom. In this workshop you will conduct ESO Supernova workshops for secondary schools dealing with Optical and Radio Astronomy, gain insight into their design and experience the ideas behind them.

An Inquiry-based Teaching-Learning Sequence about advanced astrophysical concepts for upper secondary school students

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In the framework of the National Scientific Degrees Plan, physics and astronomy education researchers at the Department of Physics of Naples and at the Capodi-

monte INAF-Astronomical Observatory in Naples, designed a Teaching-Learning Sequence (TLS) about advanced topics as Sun, stars, galaxies, gravitational waves, cosmic rays. The TLS rationale is to reconstruct from the educational viewpoint the chosen topics using as key ideas cosmological distance scale, gravity, chemical composition of stars and galaxies. First, starting from basic aspects of gravity and measurements of the chemical composition, the students are introduced to the nature of stars and galaxies. Then, using cosmological distance scale, the students are familiarized with how astrophysicists validate models about the Universe. Finally, the students derive basic laws as the Hubble law and the luminosity-period relationship for the Cepheids to investigate the size of the Universe. The TLS exploits an inquiry-based methodology in which the students are guided towards the target concepts starting from example measurements on, e.g., Sun and galaxies spectra, light curves of Cepheids and Supernovae. The activities are cooperatively carried out by a professional astrophysicist and one physics education researcher. The TLS has been implemented with 20 secondary school students for a total duration of 30 hours during extra-curricular activities. Data collected include students' worksheets and interviews. Preliminary data analysis shows the need to better relate the addressed topics with the key ideas in order to facilitate the inclusion of some of the TLS activities into classroom practice.

Workshop – Informal practices in Astronomy outreach

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In this hands-on workshop, participants will have the chance to develop and test an event based on spaceEU educational and outreach activities. spaceEU is a EU funded project that builds of the legacy of Space Awareness and Universe Awareness to deliver an exciting Space Outreach and Education programme founded in an interdisciplinary and inclusive approach, that addresses the needs of girls and underprivileged minorities and thus promotes a diverse and inclusive space sector.

Astronomy education in France: survey and analysis

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We have surveyed and analysed the production of studies related to the education of astronomy in France. On top of making available a list of documents and studies that will undoubtedly be useful to teachers, this survey shows that astronomy education is a relatively new and sparse field in France, the first documents found dates from the 1980's. Also, while the first works focussed clearly on the practical pedagogical aspects, our survey clearly shows that recent developments deal rather with developmental psychology and science education. We shall report on all those aspects. Besides, we have noticed that the void left by the official bodies (Ministry of Education and its regional and local representatives, Universities) in terms of astronomy education has been filled by initiatives from associations that have produced a wealth of resources and unpublished studies.

Astronomy at Large

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In 2018, the Australian Government appointed its first Astronomer at Large. The role is dedicated to high-level advocacy, outreach and education across all areas of astronomy and space science. With a particular focus on women in STEM and the promotion of national assets such as the Square Kilometre Array and Australia's strategic partnership with ESO, the position also provides a link between the Australian astronomical community and the Government Department that provides baseline funding. In this talk, the first incumbent in the job will explain how the role came about and what it entails, with a strong emphasis on astronomy outreach and education.

Day II

Keynote 2 – Astronomy in the Curriculum and the Classroom. Where to now?

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Astronomy is a subject that can inspire, engage and enthral children. Basic astronomical concepts are found in most science curricula around the world although astronomy is seldom presented as a separate subject. Recent reviews of global curricula have identified strong similarities in content and, also, the year level at which the content are introduced. Research however reveals that it is a topic often poorly taught and one in which students complete their education with misconceptions still heavily entrenched. Many teachers lack the confidence or training to successfully address these misconceptions in order to effectively teach the required syllabus. All of these points are implicit in the establishment, value and role of the new Office of Astronomy for Education. Whilst the likelihood of astronomy ever having a central role in science curricula is slight it provides an excellent example of a gateway science. Rather than just focussing on basic astronomical concepts (though not ignoring or removing them), astronomy can also be used to engage students and help them develop critical thinking, inquiry skills, information technology, understanding of big datasets and accessing modern observing opportunities. Using examples based on recent curricula opportunities and issues at the school level are discussed, particularly in the context of the recent IAU Framework for Astronomy Literacy. Some challenges for groups working on developing or implementing new programs are presented together with a call for ongoing collaboration and sharing of best practice.

Workshop – Activities in and around planetarium

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The planetarium is a natural place to run informal education. It stands between layman and scientist with the freedom to show cosmos and natural sciences. It can be a venue for different formats. In this workshop, we would like to discuss the limitations and opportunities. We would like to use topics below as a 'cookbook' which can be used to make 'menu' of the place like a planetarium or space center. Proposed topics: – how storytelling can serve and limit explanation? – recorded lector or live presentation? – concerts, lectures, and other special events – all you need is love – how to keep a balance between science and art – live music, how far to depart? – hands-on activities/workshops/events + more can be gathered during the conference. We are open to going through these or similar topics as a workshop or debate as well.

Teaching stellar astrophysics in the Middle School

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Introducing astronomical contents beyond the well-known Solar System subjects is a challenge in Education. It has been suggested that stars are excellent examples of a variety of phenomena (heat transfer, fluid equilibrium, light) which are already an established part of the corresponding Physics courses, and serve to integrate them into a consistent body which improves the cognitive efficiency to a considerable degree. We develop and apply a didactic sequence on stars devised to target an audience of 14-15 years old students in a Brazilian Middle School. We show how these classes changed the perception of the astronomical setting for them, and follow

their cognitive evolution for a full year after the lessons. We conclude with a positive evaluation of the impact of the experience, as emerging from the applied tests. In addition, we discuss the limits of the empirical approach to science within this subject, at the edge of the “natural science” nature when compared to the Solar System contents much easier to be directly experienced.

Workshop – Promoting diversity through astronomy education

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Science, Technology, Engineering and Mathematics (STEM) knowledge and skills are increasingly important for participation in 21st-century society as well as for employment. However, studies show that STEM activities may alienate girls and minorities from pursuing a career in STEM fields. One of the goals of the Dutch National Research Agenda is to make the student population majoring in science as diverse as the Dutch population by 2040. In this project, we aim to design inclusive STEM educational activities appealing to the diverse population of Dutch elementary school children (9-12 years old) based on cutting-edge research astronomy topics of gravity and light. These activities have been developed in co-creation sessions by researchers and professionals in astrophysics, physics, science communication, and science education. The activities will also be tested and reviewed by elementary school teachers and children, and peer-reviewed through IAU astroEDU. In this workshop, we ask the participants to be part of the co-creation process and think about concrete instructional strategies for astronomy projects to make them more diverse and inclusive. We will employ Gamestorming exercises to review some already developed materials and think of possible instructional strategies together. This workshop will help us to refine our designed materials and make them ready for the testing and implementation phase. Let's work together on how to make astronomy activities in education as diverse, representative and inclusive as possible, with options to differentiate for different learning preferences, learning levels, interests and points of view of young learners.

Teacher Training and School Curriculum: Examples from Canada

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When offering astronomy workshops for teachers, how closely should we follow the expected school curriculum? Each province across Canada has its own science curriculum, which creates a challenge for pan-Canadian programs such as Discover the Universe. Our online astronomy training program for teachers has navigated the similarities and differences in these curricula for nearly 10 years. During this presentation, I will discuss the challenges and constraints of offering online training adapted for several curricula, the solutions we are using, as well as the recent inclusion of Indigenous knowledge.

Inspiring Educators via Astronomy Teacher Training Workshop in Thailand

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“The Astronomy Teacher Training Workshop” is a workshop series for science teachers in Thailand with the ultimate goal to educate and inspire participants who can further inspire students across Thailand on the topic of astronomy. The workshop can be separate into three levels. The “Basic Workshop” are held five times annually across different regions of Thailand with the main purpose to inspire astronomy teachers so they can further inspire many more students. The basic workshop focuses on classroom activities and introducing participants to basic stargazing and astronomy as extra-curricular activities. Participants also learn the basics of telescope and

organizing star party events. The “Intermediate Workshop” focuses heavily on the extra curricular aspects where participants learn fundamental amateur astronomy skills that helps them becoming supervisors to school astronomy club. Participants receives hands-on experience on practical astronomical knowledge and able to organize and lead their own star parties. The “Advance Workshop” focus on project-based learning in astronomy and aimed to produce advisors to student astronomical science projects. The workshop series has been running annually since 2009 and the teacher network resulting from the workshop has been fundamental in allowing the National Astronomical Research Institute of Thailand (NARIT) to coordinate a national effort in organizing astronomical events.

Cosmic Mining: involving students in real astronomy research

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The Institute for Research in Schools has partnered with the UK Astronomy Technology Centre to involve secondary school students in identifying potential targets for the James Webb Space Telescope. Students are working with around 8,000 spectroscopic observations of stars taken by the Spitzer Space Telescope to identify where in their lifecycle they are. Interesting candidates for further study are being looked for in amongst this data and students will partner with astronomers to support the submission of a proposal for observing time. Over thirty schools across the UK and Europe are partnering with astronomers on this project. We report on the methods and approach used to develop the knowledge and skills of participants and the impact it has had on them. Insights and feedback from project partners including teachers, students, astronomers and public engagement professionals will be shared along with recommendations on how to develop your own effective research collaboration with schools using authentic research data. This project is part of a national campaign of public engagement with the James Webb Space Telescope co-ordinated by the Science and Technologies Facilities Council. Project team members include: Laura Thomas, Director of Education, Institute for Research in Schools Dr Olivia Johnson, Public Engagement Programme Manager, Science and Technologies Facilities Council Dr Alistair Bruce, PDRA, Institute for Astronomy Dr Olivia Jones, Rutherford International Fellow, UK Astronomy Technology Centre.

Workshop – Visual Thinking Strategy Approaches to Teaching Astronomy

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Visual Thinking Strategies (VTS) is an approach to teaching art that has gained resonance in its applicability to the teaching science. An art-based approaches to teaching astronomy has an appeal to youth who may identify with art more than with science or who view science as a static rather than dynamic process. Since students with strong visual-spatial thinking skills can be successful in either art or science careers we feel that stronger efforts need to be made to add some of the pedagogical techniques that work in the art education field to science education. In this workshop we introduce and practice the basics of the Visual Thinking Strategy approach used in art museums and in art instruction to create a more interactive learning environment for astronomy. This approach not only promotes a deep appreciation of astronomical imagery but also stimulates and encourages questioning and inquiry. The VTS approach allows students to see the mystery and questions at the heart of science and to appreciate the science investigatory process, thus countering a common misperception that science is memorization of factoids. We believe that the VTS approach, and other art-related approaches, can be very effective in promoting inclusion, diversity, equity, and empathy in communicating astronomy.

“Cosmo Explorers”: videogames at school for STEM

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Cosmo Explorers is a project aimed at developing novel and different strategies in formal education context (11-18 years old students) using videogames for educational purposes. Teachers encourage students to play with a videogame in the classroom to learn not only STEM, but also soft skills and teamwork attitude while having fun. The core of Cosmo Explorers is a competition for the creation of the best space exploration program using the videogame Kerbal Space program (KSP). KSP is a space flight simulator that allows the player to experiment with the construction of rockets, satellites, spacecraft and rovers, send them into orbit or undertake long interplanetary journeys taking into account gravity, thrust of the engines, fuel availability, energy supply, aerodynamics and much more. The flexible and modular nature of the project allows each teacher to fine-tune the activities according to their needs, moving from skills development (such as management of group work, solution of complex problems, management of medium-long term projects, learning from mistakes, ability to forecast, risk assessment and decision making, digital skills) through educational contents (kinematics and forces, gravitation, celestial mechanics, technology, economy). The project (granted by the Italian Education and Research Ministry MIUR) was led by Infini.to – Planetarium of Turin with the National Institute for Astrophysics (INAF) and ALTEC (Aerospace Logistics Technology Engineering Company). It had a duration of 24 months and involved several teams for a total of more than 100 teachers and 1.000 students all over Italy.

Workshop – Earth Rising

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Young people feel increasingly overwhelmed with the burden of issues such as biodiversity loss, increasing global temperatures and food security as a direct result of environmental degradation of planet Earth. This phenomenon, recently dubbed ‘eco-anxiety’, requires an array of solutions – and one that holds great potential, is that of astronomy education. The power of astronomy education to evoke an awareness of our place in the Universe and an innate understanding of Earth has strong historical roots. In more recent times, this was encapsulated in the response to “the most influential environmental photograph ever taken”. Taken during a lunar orbit on December 24, 1968, ‘Earthrise’ is noted as one of the fundamental catalysts for the global environmental movement. As today’s students take to the streets across the globe to demand governments to put environmental protection high on the political agenda and address the climate crisis, educators are faced with key challenges: how do we incorporate environmental edu-

cation into our curricula? How do we make people more aware of their environment? How do we prepare the next generation for the future? How do we get people to act in an environmentally responsible way? In this workshop, we want to discuss the links between astronomy and environmental education and explore the different goals between 'traditional' and 'active' astronomy/environmental education. Together with participants, we will look at what opportunities we all have to move beyond disciplinary boundaries and exploit such connections in an interactive and stimulating way.

Voices coming out of hands: Teaching Astronomy for the Deaf

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Astronomy learning among deaf is currently a remote possibility in Brazil, something that hardly happens or, when it happens, is usually very limited. In order to improve Astronomy Education among deaf children and school-aged youth, it is necessary to expand the resources of the Brazilian Language of Signals (Libras, acronym in Brazilian Portuguese), strengthen the preparation of teachers, develop teaching resources more aligned with sensory experience of the deaf and even rethinking organizational aspects in classroom settings. Astronomy is very important for the educational background of the deaf and has a significant role in its introduction to the fundamentals of science and motivation for scientific knowledge.

Working with authentic astronomical data in an education setting – a practical perspective

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Summer internships for high school students at Haus der Astronomie, which we have offered since 2009, we try to make use of archival data to provide genuine research experience to our participants. This talk recounts how our practices in using archival image and spectral data have evolved over time, describes some of the challenges of working with real data (and some of the resulting limitations) that our students have faced, and closes with some more general thoughts on integrating data into educational settings, and on what research astronomers can do facilitate educational use of their data.

Implementing project-based learning to Astronomy Education at the national level

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We introduce a project-based learning as a supplementary extra-curricular activity to expand upon students' prior interests in astronomy. Participating high school students from Thailand are engaged in a long-term project-based learning via astronomy research project. After an introductory workshop, students are encouraged to come up with their own topic and problem statement in which they embark on a 10-month journey to investigate, understand, and attempt to devise a predictive model that would describe the laws of nature based on their observations. A great emphasis is put on engaging the student to question and pursue their own interests and curiosities. Topics range from basic naked eye observations, invention, computer programming, to a more conventional observational astronomy using robotic telescope to perform astrometric and photometric measurements. Supervision is offered via a system of mentors/advisors but is strictly limited in favor for self-investigation. Progress and regular updates by the students are tracked remotely via social media. Students present their final works in an annual astronomical student conference at the national and international level. As a result, students are able to expand on their own curiosities, gain valuable hands-on experience on critical-thinking, problem-solving, and able to present their work in public. This on-going annual project has far-reaching consequences that is slowly transforming the overall landscape of Thailand secondary level astronomy education.

INTERSTELLAR – INTERdisciplinary Study of (sTudEnt) Learning in a pLANetaRium

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Research shows that many astronomical phenomena are difficult to grasp and to teach. As visualising the night sky is a main goal of a planetarium, it might be a powerful setting to enhance (student) learning of these concepts. Planetariums have a long history in supporting astronomy interest, but the impact of the planetarium visits on the effective learning is vastly unexplored and there are still many open questions about the role the unique visualisation possibilities in a dome can play in educating various kinds of audiences. INTERSTELLAR is an ambitious long-term interdisciplinary research programme on the learning in a planetarium. It is rooted in a unique collaboration between the Planetarium of Brussels and different research groups of the KU Leuven, which together comprise a wide range of expertise, from Physics Education Research (PER) over Cognitive and Educational Psychology to Astronomy and Astrophysics. INTERSTELLAR aims at designing a research-based learning environment for astronomical and astrophysical concepts by fully exploiting the unique visualisation possibilities of the Planetarium. Until now, very few planetariums worldwide offer such research-based learning environments to specific audiences as they mostly capitalise on the immersive nature of the displays and the engagement of the audience. The development of an astronomy education research programme for the Planetarium of Brussels would make it unique in Europe by providing carefully designed and tested educational programmes. In the presentation, we will present the aims and general research plan of this ambitious programme and touch upon the general research methodology.

An Analysis of Peer-Reviewed Papers on Astronomy Education Published from 2007 to 2018 in Japan

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We analyzed 102 peer-reviewed papers on astronomy education published in academic journals from 2007 to 2012 in Japan. There is no single primary academic journal for astronomy education research, and the papers have been published in various journals. About one fourth of the papers are related to topics in elementary school. In total, 80 % of the papers are related to school curriculum contents. On the other hand, the number of papers on training of in-service teachers and museum curators is small. About one third of the papers deal with the lunar phase, which is one of the main topics in elementary school astronomy curriculum. About two thirds of the papers are related to the Solar System bodies, which means that most of the research papers do not deal with the realm of stars and galaxies. Compared with cases in international journals and meetings, Japanese astronomy education research focuses on issues in elementary school contents, and in terms of concept, research related to Sun-Moon-Earth system is most common and that on Earth is rare. Most of the papers present the development of teaching material and examples of implementation using the materials in class and evaluate the practice using the post-test questionnaire method. As for the first author of the paper, more than two thirds are university staff and most of the others are school teachers. The number of papers whose first authors are students is small, meaning that the Japanese community needs more effort in astronomy education researcher training.

What do teachers need to lead enquiry-based projects in Astronomy?

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In many European countries student interest in the STEM careers is low [1]. What can an R&D center do to meet the challenge of engaging students with STEM? In the IAC we have been running the educational project PETeR since 2007. PETeR is an enquiry-based online lab (www.iac.es/peter) which dedicates observing time with professional robotic telescopes to activities and e-science projects aimed at primary and secondary students. During the first years of the project the requests for observations were low and one of the reasons given by the teachers was their lack of knowledge to guide scientific projects in Astronomy. Therefore, in 2015 we began to carry out teacher training courses with three clear objectives:

- to bring Astronomy closer to teachers in an enjoyable way so that they lose the fear of working on these topics with their students;
- to provide them with the tools and knowledge so that they can introduce it in a practical way and develop real enquiry-based projects; and
- to raise awareness of the project.

In these five years we have trained over 250 teachers, most of them from Spain, but also from other European countries, in several courses organized in collaboration with other institutions like NUCLIO, the Faulkes Telescope Project, the National Schools' Observatory and the Department of Education of the Canary Islands. In this talk I will present some of the results we have obtained and a summary of the lessons learnt so far. [1] European Commission, Eurostat – Tertiary education statistics (2018).

Female participation in thesis on astronomy education in Brazil

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This paper presents an overview of Brazilian researches on astronomy education from thesis, analyzing the gender of authorship and investigating the female participation in this field. The database allow us to raise some questions about amount male and female participation in scientific production and about universities, gender of supervisor and type of academic production. The objective is to provide a view about female authorship historical in this area and reflecting about the situation with lens of gender literature, especially the questions about women in science. With the support of literature related to the state-of-art research, the data were analyzed and organized according to the gender of the authors, from 1973 to 2017. With a total of 374 MSc and PhD thesis, 136 (36,4%) were made by women, and 237 (63,4%) by male. From this survey, several elements emerge, reflecting on produced works and gender issues implied in the constitution of the astronomy education research area. The results also show trends in comparison with researches on female participation in Astronomy and Physics. This study should encourage the participation of women in the astronomy education research.

Literature review of Master and Doctoral thesis in Astronomy Education in Portugal: overview, progresses and setbacks

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We present the major findings of the work developed until now towards a fine-grain content analysis of Master and Doctoral thesis in Astronomy Education published in Portugal. The categories were the same used by one of us in previous state-of-the-art research, that is: year of publication, institution, school grade level, focus of the study and type of academic research. To this phase, we identified a total of 110 thesis produced between 1999 and 2018. While 58 are available online and thus allowing easy access and study, 52 are not. This implied an effort to reach to those in order to scan the content and perform the analysis. To this stage, we have 15 paper copies that we intend to digitalize with a remaining figure of 37 thesis, mainly, in the Porto's Faculty of Science Library. Even with these limitations, we could identify two peaks of academic production in this area. The first in 2001 can be associated as the outcome of the first post-graduation in Astronomy established at Porto University (from where 68% of the thesis were developed), and the second in 2012 which would certainly be related to the International Year of Astronomy in 2009. Also, because astronomy is in the curriculum explicitly at the 7th grade, a significative amount of work is related to the production of materials in order to help teachers at this level. Additionally, if the initial thesis were addressed to high school and university education, later, essentially after 2010, a concern with Astronomy education at early years of schooling begin to increase in the overall production.

Teaching astronomy in Russian schools: challenges, approaches and possible solutions

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Astronomy was eliminated from the high school curriculum in Russia in 2009 in the International Year of Astronomy. Although the subject was restored in 2017 surveys showed no improvement in astronomy knowledge over two years. The roots of this impasse lie in the absence of practical activities in astronomy classes. Interest and enthusiasm in astronomy and hence the knowledge of the subject could not be reached without real astronomical observations and workshops. (Historically almost every school in the USSR had telescopes and teachers were trained to conduct astronomical observations.) Schools in today's Russia are not equipped with telescopes. For

example, the Regional Ministry of education of Irkutsk oblast (Siberia), for example, has no plans to equip schools with any astronomical instruments. With this situation in mind, possible solutions to these problems are proposed. Firsthand experience is outlined of a collaborative work of the Irkutsk planetarium, regional amateur astronomers' community and school teachers in Irkutsk region. We give some proposals to teachers looking to boost the astronomy proficiency of their students.

Why are you going to Tamra?

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“Why are you going to Tamra?”, the head of security for El Al Airlines at Pearson International Airport in Toronto, Canada asked of me as I was en-route to Tel Aviv. That question, and the forty-five minutes we were interviewed at security, were done for security reasons. I understood the need for increased security prior to boarding a flight for the Middle East as there had been a recent increase of violence in the Gaza. The question, however, had an undertone. Why were ‘you’ – as in me, a Canadian Jewish man and his twelve year old daughter, going to Tamra, an Arab city in Israel. What could I possibly be doing there, and how would I know anyone from there well enough such that we would be welcomed guests in their home during our visit? The answer was truthful and innocent: we were going to see our friends, who are Arab, and I was to continue working on using astronomy education as the focal point for breaking down societally imposed barriers. This presentation will share experiences of using ethnoastronomy as a means to connect people across cultures and religions, and highlight the often racially charged challenges that manifest when walking this path.

**Blu and the sky.
An astronomical education
project for kindergartens based
on the model of metacognitive
cooperative learning**

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The creation of the character of Blu stems from the need to find an effective interlocutor in astronomical education for kindergarten (and primary school) sector: Blu is not a dispenser of knowledge, Blu knows nothing, does not know our Planet, he doesn't even know what it is. Children tell him about our world and the Universe, with simple words. Who reads and listens his adventures could explain him many things, maybe obvious and trivial for us but not for Blu. What are days and night? What is a star? And what is the light? Each child discover himself/herself as the bearer of knowledge and experiences and becomes aware of being part of a Universe full of lot of things to be explored. The stories of Blu become an interactive e-book, developed with experts in instructional design and Universal design for learning, easily accessible to all thanks to the highly legible characters, the transcription of the text in AAC and the synchronized reading of the text. The final product is completed with accompanied by multimedia contents to be downloaded, such as the printable version of the story, the cards for educational activities and the audio book. The talk will present the general outline of the project and its application during the 2018/19 school year in two kindergarten schools of the Cagliari hinterland.

Einstein Schools Programme: A Project-Based Approach to Encourage Worldwide School Collaboration

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The Einstein Schools Programme, a global project of the International Astronomical Union 100 Years Celebration, helps schools all over the world to explore the exciting role of gravity in modern astronomy. It is designed to encourage in the spirit of IAU collaborations among schools worldwide. Einstein Schools launched on 1 October 2018, and currently more than 200 schools from 45 countries have signed up. The project encourages teachers to form a student team and it gives them the tools to carry out a plan to explore a topic of choice with their team. An important aspect of the programme is to provide each Einstein School with a science mentor who helps teachers to more confidently explore gravity and astronomy topics with their students, and who act as an inspiring role model for students. During the first year of the programme, we have focused on reaching schools all over the world, creating a website with high-quality resources on gravity and astronomy, communicating regularly with the teachers, finding mentors and pairing them up with schools, and developing a model for schools to become certified Einstein Schools. After this first phase, it is time to reflect on the successes and challenges of the programme. For example, how do we keep teachers from so many different countries engaged and motivated? How do we create a sense of community? In this talk, we want to discuss these successes and challenges and we want to share our plans and ideas for the future.

Day III

Keynote 3 – Collaboration and the fear of losing oneself: Teacher Training and Space Education in Europe

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Teachers struggle with lack of time, excess of curricula and often, isolation. Many European initiatives have helped change this through mainly professional development and collaboration. However, collaboration often times causes fear of losing oneself. During this session we talk about the importance of collaboration in Science, Technology, Engineering and Mathematics in general, and Astronomy education in particular, and ways to minimise that fear in teachers and students through different examples used by STEM education projects, including Astronomy, for primary/ secondary school teachers.

Effective Climate Change Communication Strategies for Astronomers

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From a social, environmental, and political standpoint, climate change is becoming the defining topic of our time. The need to address climate change has become immediate, with only 12 years to drastically reduce carbon emissions in order to avoid potentially irreversible and catastrophic effects. Unfortunately the public is ill-informed about climate change and its consequences. Fortunately astronomers are well-poised to educate about it. In the classroom and through public talks, planetariums, and K-12 outreach, we reach a large audience. Astronomy is closely connected to the science of climate change, and it is arguably the most important topic we include in our curriculum. Due to misinformation and disinformation, climate change communication is different than for other areas of science. Bad climate communication strategies can be ineffective and even backfire, meaning that simply knowing the science content is not enough to effectively teach it. Talking about climate change requires using effective strategies, for which there is now a considerable body of research. As part of my talk I will introduce (1) resources that will improve their science content knowledge about climate change, (2) effective interactive and inclusive methods for teaching the topic in Astro 101 classes, and (3) established strategies for engaging the public.

astroEDU – now and Future

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astroEDU is a peer-reviewed astronomy education activity repository. Launched in 2013, it currently has over 100 activities spanning astronomy, Earth and space sciences. Over the course of its history, astroEDU has continuing developed and iterated on its approach to undertaken peer review to provide a robust method of quality control. In this talk, the history of astroEDU will be briefly outlined and the new major astroEDU project under development drawing on the recently completed OECD astronomy curriculum review as well as the proposed definition of astronomy literacy published by the IAU.

Online team work in astronomy and planetary science at the Open University

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The Open University (OU) is one of the largest universities in Europe and unique among UK universities in that its curriculum is open to all, delivered entirely by distance teaching, and studied predominantly on a part-time basis. At present there are approximately 1500 students enrolled on undergraduate or taught postgraduate modules in the astronomy, planetary science and space science domain. To facilitate teaching practical science at a distance the OU developed the award-winning OpenSTEM Labs, providing students with real-time control of remote experiments, including our robotic optical observatories PIRATE and COAST in Tenerife, a radio telescope at the OU's campus, and a planetary surface simulation yard, currently set up for a Mars rover mission simulation. These facilities lend themselves to team working projects, thus maximising the number of students who benefit from a limited resource, and providing a framework for distance learners – who are not co-located and would normally study essentially in isolation – to develop their employability-enhancing team working skills. Here we report on three different team-working projects in astronomy and planetary science, two involving OpenSTEM Labs assets, and one based on data from the SDSS. The projects are somewhat open-ended and designed such that team decisions are required throughout. We present an early analysis of the student experience on these three projects. We combine quantitative and qualitative analysis of online forum discussions with insights drawn from in-depth interviews with students to highlight the factors that may be important in the success of online team work in an astronomy and planetary science context.

The Moon Camp Challenge – Learning STEM by designing a Moon Base

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In this presentation, we will highlight the importance of using innovative educational methodologies and techniques to engage students in STEM learning, and present the outcome of the first Moon Camp Challenge. The Moon Camp Challenge participants have to 3D design their own version of a Moon base which is able to sustain at least two astronauts. The project is open worldwide and it is organised by the European Space Agency and Airbus Foundation, in partnership with Autodesk. The challenge targets primary and secondary school student teams (2 to 4 students each), in two different age categories. Category 1 (up to 12 years old) foresees the use of the Tinkercad 3D design tool, and Category 2 (13-18 years old) makes use of Fusion 360. In their design, the students need to envisage the use of local lunar resources such as lunar soil or water ice. Then they have to describe how their design provides protection from radiation and meteorites, and explain how they would obtain energy and food supplies. Finally, they have to 3D design their Moon base. The Moon Camp Challenge features preparatory classroom activities based on learning-by-design and science experimentation. First, the students will run a number of curricular scientific experiments using the Moon as a real-life scientific context. Then they have to apply the acquired knowledge in an interdisciplinary manner in order to design their own Moon Camp. The Moon Camp Challenge covers and interlinks different STEM subjects including Physics, Chemistry, Biology, Maths, Engineering, Astronomy and Design/3D Modelling.

An overview of the current status of Astronomy Education Research

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When the landscape of a research area is analyzed, its scientific production is mainly identified by the following publications: theses, monographs, conference proceedings and journal articles. The present work deals with review articles published in Astronomy Education Research (AER), their results and suggestions. Later on we present surveys based on categories like: year, institution, school level, focus of the study in education, type of academic research and the theoretical framework taken from IAU, RELEA and other sources. These surveys show trends and gaps, already discussed in the literature of the area and point towards the less addressed contents and recommendations for further work. The answers to a questionnaire of IAU CC1 and WG on Theory and Methods in Astronomy Education members about the achievements and challenges of AER are discussed. Recent surveys of publications from some countries are also shown evidencing the dispersion of AE literature. The role and goals of astronomy teaching are discussed next considering contents, methods, levels, resources and purposes. Given the needs and complexity of education nowadays and the role of astronomy in this context, the potential of education research is also evaluated, considering knowledge, practices, policies and the training of teachers. The formation of a community in an area where the astronomers are trained as scientists and the need of training of education researchers are considered. About this, the different approach of hard sciences, very different from the social sciences in which education is inserted is pointed out and discussed. Finally, collaborations for surveys, literature reviews and the advertisement of such materials, aiming to strengthen the training of researchers and the practitioners as well are also encouraged.

Short review of robotic telescopes in education

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In the recent decade, particularly over the last few years, developments in making research-grade telescope technology available to the classroom at little to no cost have been rapid. With the growth of the Las Cumbres Observatory, SkyNET and iTelescope networks, as well as a host of smaller networks, the possibilities for schools anywhere around the globe to utilise real data in their classroom has become viable. In this talk, the current state of robotic telescopes in education is outlined as well as a variety of success stories, possibilities for potential users and current problems being tackled by the field.

Review of Astronomy in the OECD curriculum

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This talk highlights the results from a study which has reviewed the presence of astronomy in the school curriculum of the Organisation for Economic and Co-operative Development (OECD) member. Countries, including China and South Africa. This review provides a preliminary framework for determining how best astronomy can be included in curricula in the context of the peer-reviewed resources from astro-EDU, and the Big Ideas in Astronomy literacy framework.

Astronomy School Education in Chile

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Chile is home to several of the world's biggest telescopes, but even though the Chilean population values astronomy as a national attribute, less than a third of them declare having some astronomical knowledge (Marinovic, 2016). In this regard, in the last years there was a significant growth in astronomy outreach and education programs in Chile, as well as an increase of astronomical topics in the National School Curriculum, but until recently there was no research on astronomy education at the Chilean context. Thus, the purpose of this talk is to discuss, for the first time with research evidence, the current state of astronomy school education in Chile. We present the results of assessing the astronomical knowledge of 169 K-12 teachers and 159 students (ages 15 to 17) using the Astronomy Diagnostic Test (ADT 2.0; Hufnagel, 2002), which shows a high presence of alternative conceptions in curricular topics that agree with those identified in several international studies (Bailey, 2011). We also present preliminary results from a study of teachers' perceptions on astronomy education in Chile, analyzed with Grounded Theory, and discuss the effectiveness of astronomical courses and workshops offered to Chilean teachers and students.

Teaching astronomy for non-science students

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Astronomy is a blessed field as it comprises both science and non-science. In Universiti Teknologi MARA (UiTM), there is only one (1) subject dedicated for astronomy especially for non-science students. We have a designated course that bridge between astronomy, culture and religion. Through this subject, the students are exposed to aesthetics, issues and research in astronomy. Other than lecture, the students are encouraged actively participate in Massive Open Online Course (MOOC). Indoor activity is not enough, therefore, the students are given opportunity to get involved with the research by way of conducting mini-projects. The students are required to conduct astronomy project like sunspot observation, urban night light pollution monitoring, building astronomical models and astronomy-based games. We adopted continuous assessment as the best practice for more hands-on involvement and we believe in start small and be consistent.

21 years astronomy activity of teachers in Iran and create astronomy union for teachers

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Iranian teacher's astronomy Union is the first interdisciplinary teacher union of Iran those teachers from each three levels: Elementary, Secondary school and high school can be its member and work in astronomy and nature fields simultaneously. Before forming this union, although there are some contents related to the astronomy there

is not any schedule or widespread and purposeful attempts to teach astronomy to the teachers, developing content knowledge and practical knowledge and utilize the great sky of Iran in order to teach astronomy to the students. Along approval, formation, and convincing the ministry of education of Iran about the existence of teacher astronomy union, there's been widespread attempts by the management of Hassan Baghbani from 21 years ago till now in Bushehr. Ministry of education of Iran found the Astronomy as an important and useful field and approved the formation of ITAU in 2015, as a result of 20 years attempts. After many years of activities there are 20 active local groups of teachers and students in Bushehr and 9 more associations in other provinces of Iran. This association is busy with teaching the teachers and teacher-students especially in underprivileged. Till now more than 2000 teachers have gained education in this field from this union. Also, about 10000 students annually participate in different activities and workshops in different ways. Teaching astronomy to the teachers, motivating the teachers, and forming local teacher groups are some of the aims of this union.

Integrating Space Science Education to the Basic Education Curriculum: A Case Study of the Philippines

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Despite the interest among young students, space science education in developing countries such as the Philippines is a challenging endeavor mainly due to the lack of institutional support and integration into the educational system. The Philippines initiated a Space Science Program (SSP) Pilot Testing from 2013 to 2018 to enhance the state of astronomy and space education in the country. Space science classes were conducted as an 80-minute weekly after-school class for pre-school, elementary and high school students of Diliman Preparatory School. Each class was conducted on a team-teaching basis and utilized various modes of teaching, from traditional lectures to hands-on experiments to ICT-based education, in order to enhance the student's learning experience and emphasize the learning concepts and objectives. Unique topics included in the Student's Manual developed by the authors ranges from atmospheric science, Solar System, astronomical observation, galactic astronomy and satellite technology. As a counterpart, science teachers in the school were also trained and provided a Teacher's Handbook to supplement their knowledge in astronomy and space science. It was observed that elementary students demonstrated the

strongest interest in learning astronomical concepts while high school students had lesser enthusiasm, mainly attributed to the increased academic load of high school students. In contrast to the government-prescribed curriculum, it was observed that the concepts were presented in a more systematic manner and appropriate for the student's current grade level. The SSP Program will be further tested in selected schools in the Philippines beginning in 2020 as part of the K-12 curriculum.

Session III.II

Posters

Day I

The heterogeneity and variability of Astronomy on Tap worldwide public outreach events

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Astronomy on Tap (AoT) is a constellation of free public outreach events combining engaging science presentations with music, games, and prizes in a fun, interactive atmosphere. AoT events feature one or more presentations given primarily by local professional scientists and graduate students, but also by visiting scientists, undergraduate students, educators, amateur astronomers, writers, artists, and other astronomy enthusiasts. Events are held at social venues like bars, breweries, coffee shops, and art galleries in order to bring science, the stories behind the research, and updates on the latest astronomy news directly to the public in a relaxed, informal atmosphere. The flexible format and content of a typical AoT event is easy to adapt and expand based on the priorities, resources, and interests of local organisers. In this poster we highlight the heterogeneity and variability of AoT events, including how organisers have modified the typical AoT format to best take advantage of local resources and meet the needs and interests of local organisers and audiences.

Sky Explorers' festival

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The MEHR Observatory in southern Iran is Center of the Ministry of Education for astronomy. The Observatory was established in 2005 and has designed and implemented many projects and activities for teachers and students during 14 years. The Student Festival is the Sky explorers festival; it's an astronomical and environmental event that has held since 2013 in the Observatory every March. The festival can train astronomy, teamwork and nature conservation. Each team can be 4 or 5 student for registration and they can receive scientific projects every November. Student groups have 5 months time to complete these projects in their school or city and village. The festival includes astronomy and environmental training. The observatory has a large garden; Students have 24 hours camping in there. Every 25 students have a supervisor. This supervisor is a student who has trained the necessary skills in astronomy, nature and teamwork. Tenting, observing the Sun, making sunbathing, photo galleries, info graphics, making astronomical instruments, working with telescopes, observing planets and Moon, bird watching are among the most important parts of the festival. Over the six years, 6350 students have participated; of which more than 5,500 were girl. The crucial point of this festival is that all parts are from registration to execution do by students. The main goals of the festival are: learning teamwork, proper behavior with nature, self-esteem, astronomy education and its practical applications. Many of these students, after completing the program, set up astronomy groups at their school or place of residence.

Astronomy Learning Strategy in Modern Islamic Boarding School (Case Study of Science Approach with the Qur'an at Middle School Level)

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Learning activities in modern Islamic boarding school is generally a complex and integrated learning based on the Holy Qur'an. In practice, many juxtapose various subject with the text of the Qur'an. A new challenge arise when faced with astronomy. Astronomy material is still seen as a difficult material to convey in learning. Especially because of its complexity, the teacher competence and the lack of adequate facilities such as reference books or other supporting learning means. Astronomy is actually one of the basic knowledge of science studied at middle school level. Although there are not astronomy subjects specifically in the curriculum, in fact, there are astronomy material in science learning material and the existence of prestigious

events such as the science olympiad both nationally and internationally requires students in boarding school to also be able to master in astronomy. The purpose of this study is to formulate an appropriate strategy for learning astronomy, which can be applied in modern Islamic boarding school, as a school that uses the Qur'anic approach to learning. This study uses qualitative studies by identifying Qur'anic texts and their interpretations relating to astronomy material at middle school level and deepening modern Islamic boarding school's curriculum.

The use of Human Orrery in teacher training, or how to introduce pre-service teachers to mathematics and science subjects by using an astronomical pedagogical tool

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We present here a training program for prospective primary teachers (PPT) based on a pedagogical astronomical tool: Human Orrery (HO). A HO integrates people directly into the experience of orbiting planets by experiencing the movements of planets around the Sun through their bodies and their movements. It unifies aspects of physics and mathematics subjects standing thus as an interdisciplinary tool for education. The training program aimed first at making PPT familiar with astronomy aspects that they will have later to teach in their classes and second to go beyond simple front teaching by making their own actions central to the demonstration. The program runs for five 3-hours modules in teacher training institute and afterwards for a one-day work and observation in primary schools with pupils aged 8-10 years. The pupils were introduced to astronomy concepts by their teachers during the two preceding months. The PPT, one group per class, had to implement an activity they had designed within the academic modules. Each activity was conceived into two phases using HO in the courtyard and a printed version of the HO in the classroom. Connection between meso-space and micro-space had thus to be considered. The PPT recorded the implemen-

tations and used these records in a reflective practice session at the afternoon. We will present the design of the training program, the content of the implemented activities, the observations of the PPT and our own feedback on the program.

Let's Learning Astronomy? A Meaningful Experience in Training Of Physics Teachers

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This article aims to present students' studies experience from their academic course in Physics through the Institutional Scholarship Initiative Program, having astronomy as transversal area. These experiments took place at João Silva Public School with 10 to 14-year-old students. It is used the playfulness as the mainspring of the process of knowledge construction in this scientific research. The methodological procedure is based on the formation of groups of students that are monitored and guided by these graduate students through stages of observation of physical phenomena, recording, experimentation and subsequent socialization of the stages experienced. It is our goal to sharpen the scientific spirit, articulating processes of hypothesis formulation and strengthening of answers that start from the investigation and study of basic concepts related to Astronomy in all pedagogical moments with the students. The groups designed their own observation equipments, observe, identify and register the movements of celestial stars such as the angular position of the sunset, angular movement of the planets with a focus on the planets that have an apparent retrograde movement, zodiacal constellation movement, and the movement of the indigenous constellations of Tupi origin. From the thematic division, students observe real situations and begin to interpret them, introducing parallel knowledge in scientific theories, thus the students are challenged to express what they are thinking about the situations. It was verified that the methodological principle of exploring the research as articulating axis, generated a significant learning of astronomy basic concepts.

The Motions of Celestial Bodies – A teaching proposal for elementary school students

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Through daily observations and supported by easy construction and mounting equipments, we can make night sky observation become much more interesting and stimulate middle school students to perform such task for a scientific thought construction. With the proposed project, first doubts arise: is the apparent motion of stars, by night sky observation, constant all year long? What would be the result if we did azimuth and inclination angle measurement of some stars and constellations? Students analyse angular motion of stars and constellations, during all year long, to understand how is the apparent motion of stars, by registering azimuth and inclination angles, identifying constellations trajectory in heavenly sphere during during year, and seeking for explain this movement, by relating it to Earth's translation movement. Hour and place were chosen to do night sky observation once a week, for the register of stars passage in heavenly sphere. This project is being developed by elementary education/middle school students from Imperatriz city, from Brazil, oriented by undergraduate students. In just two observations, with a week between each one, we registered an alteration of Crux Constellation angular position, an alteration of 7° of inclination and 0° azimuth. These apparent movements are direct consequence of Earth's translation movement. Student concludes that, due the translation movement in following day, at the same time, one sees a lightly advanced heavenly sphere, in relation to the previous day.

Night, sky and stars : providing pedagogical material for autonomous teachers

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We wish to give teachers the opportunity to introduce in their lessons astronomical notions, and to have ready-to-use material that would facilitate this task. To accomplish this, at the Observatoire de la Côte d'Azur (Nice, France) we have developed pedagogical material explaining activities to make children better understand astronomy. For each activity we have developed a teacher sheet, a student sheet and a construction sheet when necessary. We will show several of these activities dealing with different subjects: light and spectra, constellations, chemical composition of the Sun, stellar spectra, Stellarium.

Astronomy in the Brazilian Cerrado Sky

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In the Midwest of Brazil is localized one of the most important ecosystems in the world known as Cerrado. In this place, have been developed several activities of the Astronomy. This is a project started in 2009, linked to Federal University of the Goiás – Regional Jataí (UFG) and which is based on the work for the dissemination and popularization of astronomy through various activities such as sessions of Planetarium, astronomical observation practices and workshops organized with the aim of working in a environment fun and interactive the concepts of the astronomy and their relationships with other fields of knowledge. Have been developed educational activities whose approach are the concepts of astronomy in a way correlated to the way of living and regional production modes.

The ESO Astronomy Winter Camp

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A memorable experience for a selected group of students. Every year, for the past six years, ESO has organized, in collaboration with the Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVda) and the science education event organiser Sterrenlab, an astronomy camp on the slopes of the Italian Alps.

Almost 60 students, mainly from the ESO Member states and the countries participating to the ESO Science Outreach Network, have been selected each year to attend to astronomy lectures on a different subject every year, to realize their own observation, to get at least a taste of the snow covering the mountain (a novel experience for many), and all in all to spend a week of their young life in a dramatically different environment.

As ESON Italy representative I have attended most of the Camps, delivered lectures and seen the student at work. I also have followed a few of them in their lives after the Camp. I will talk about how the camp is structured, and why I believe, together with the researchers of the OAVda, this is a great experience for youths. I will try to convey what was hard to reach and what worked best, from the point of view of disseminating a knowledge of astronomy, but also, through astronomical observation, teach the students to be masters of themselves, and to prepare their future successes.

In collaboration with the OAVda: Jean Marc Christille, Davide Cenadelli, Paolo Calcidese, Andrea Bernagozzi.

The project of the Astrophysical School “Traektoria”

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The Astrophysical School “Traektoria” is a educational project supported by the non-profit Traektoria Foundation (Russia) in 2016-2019. Here we describe its details, results and perspectives.

The project brought together dozens of scientists and educators from many research institutes working in the field of astrophysics and related disciplines. The main idea of the project is to incorporate motivated high-school students in the scientific society before their graduation from the school and entering a university. The educational program of the school suggesting a consequent (non-stop) 3-year educational process touching all main topics of modern astronomy from celestial mechanics to astrobiology.

In 2016 forty high-school students were selected from 120 candidates within an all-Russia competition. During last years, the students have been invited six times for participation in face-to-face schools (7-14 days each) which were organized in various astrophysical institutions around the Europe (e.g. Special Astrophysical Observatory in Russia, Observatory of Tuorla in Finland, Alikhanyan National Lab. in Ar-

menia). The program of these meetings was fulfilled by lectures and practical work in astrophysics, physics, maths, English language and by many additional activities like school research conference, popular lectures, and sports. In the time between these meetings, all students were involved in the research projects mentoring by professional scientists. These projects are carried out remotely and some of them were finished by a peer-reviewed scientific publication.

We conclude that the project highly influenced the students' educational and professional trajectories and supported their intentions to keep evolving within the international scientific (astronomical) community.

PARST Educational Tool for Planet Positioning

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The Planets Approximation of Rising and Setting Time (PARST) educational tool is designed to estimate the rising and setting times of the five naked-eye observable planets from low-cost materials which can be portable. For the first designing, the 50-year equatorial coordinate of five planets were collected and calculated to obtain their hour angles at 0UT. Next, the rising and setting times of all planets were estimated from these hour angles. Accordingly, the periodic analysis was used to find the repeated periods. Finally, charts of each planet were designed and assembled in corresponding with the local time. The effective of this PARST tool will be statistically analyzed by paired dependent samples t-test in classroom with secondary school students, under the goal for learning progression support student understanding about planetary motions. For practical application, PARST tool can be used as a hands-out activity before night observations.

Training future astronomy teachers – modern teaching methods for a modern science

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In order to motivate science teachers to include astronomical content and especially modern astrophysics and cosmology in their classes, they do not only need basic knowledge of the most important astronomical concepts, but also methods how to teach them, making the most of science education in the digital era themselves. I will present the approach and lessons learned from the annual astronomy course the Haus der Astronomie offers at the University of Heidelberg for pre-service physics teachers. We use blended learning techniques to convey content, so that we can focus on hands-on activities and model concepts during presence phases, which is well-received by the students.

Astronomy as an integrating core for the interdisciplinary and transdisciplinary approach in educational programs

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The Romanian National Curriculum is in difficulty when it comes to implementing an interdisciplinary and transdisciplinary approach especially for middle school and high school students. Although very popular, astronomy is not currently a discipline of study in the Romanian National Curriculum even if it is the most natural interdisciplinary approach to science. We propose a study to prove that with the aid of astronomy integrating the curriculum for the two above mentioned age groups can be efficiently achieved. We design a one week pilot educational program that uses astronomy as an integrating core for the interdisciplinary and transdisciplinary approach to the National Curriculum disciplines and their content. We use the pilot program to help children understand how a different approach can help them enrich their knowledge and gain a deeper understanding of the scientific content taught in school as well as offer students astronomy related content that would otherwise not have access to. Also the pilot program will test how efficient and useful astronomy is at integrating the curriculum. The success of the pilot program both from the stu-

dents receptivity point of view and the education research point of view will decide whether this program shall become a permanent one.

Globe at Night: Turning Passion into Protection through Citizen-Science

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Globe at Night is international in nature, inviting citizen-scientists around the world to measure and submit night sky brightness observations in their locale. It is designed to raise public awareness of the disappearing starry night sky caused by light pollution. During ten-days per month of moonless evenings, citizen-scientists worldwide record the night sky brightness in a “star hunt” for the faintest star visible. People match the appearance of a constellation to one of 7 star maps of progressively fainter stars. They then submit their choice of star map on-line or with a smart phone along with their date, time and location to help create a light pollution map worldwide. The report page is found at <http://www.globeatnight.org/webapp/>.

Unique partnerships in special projects such as with the National Park Service and National Geographic Society have been used to create a night sky inventory during programs such as BioBlitz. On-the-fly mapping can be used to see contributed observations immediately. Postcards, activity guides and report pages in up to 28 languages can be found at <https://www.globeatnight.org/downloads>. STEM activities for young children (Dark Skies Rangers) and problem-based learning activities for older students (Quality Lighting Teaching Kit) are integrated with the program.

Explore the last 13 years of data (over 185,000 data points from 180 countries) using the Globe at Night interactive map (www.globeatnight.org/map/) or the Globe at Night’s map app (www.globeatnight.org/mapapp/). Data has been used for school science projects, strengthening city ordinances and monitoring conditions near observatories sites. Visit the poster to find out how.

Teen Astronomy Cafés: Exciting the Interest of Talented Youth

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NOAO started the Teen Astronomy Cafés program to excite the interest of talented youth in STEM. One Saturday a month during the academic year, high school students interact with expert astronomers who work with big data. Students learn about killer asteroids, exoplanets, lives and deaths of stars, variable stars, black holes, the structure of the Universe, gravitational lensing, dark matter, colliding galaxies, and more. The format for the cafés is a short presentation by an astronomer, a computer-based lab activity and a discussion during lunch. In a room with 15 iMacs, students explore the astronomer's research, usually using Python coding. The team includes 7 local high school students, an undergraduate coordinator, 2 grad students, the astronomer and program director. The youth leaders help with setting up, running and taking down the café. Most importantly they help their fellow students with the computer activities. Plus their feedback (and the team's) shapes and improves the program. The experience offers them training in planning, leadership, and communication skills and encourages their personal interests in STEM. Six have gone into STEM disciplines in college. Presently, 50% of the students are from C and D graded schools. Over 50% are girls. Our science cafés demonstrate that scientists play a key role in increasing student interest and curiosity about science research and in helping students get a sense of scientists as people. The cafés also demonstrate that scientists can help students see how research connects with issues important to society and with students' daily lives.

The Turn on The Night Kit: Enabling Awareness through Problem-Based Learning

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Poor quality lighting impedes astronomy research and a starry night sky, and creates safety issues, affects human circadian sensitivities, disrupts ecosystems, wastes billions of dollars/year in energy and leads to excess carbon emissions. To educate the next generation on issues and solutions to light pollution, NOAO EPO created the Quality Lighting Teaching (QLT) kit, which is now manufactured as the Turn on the Night (TotN) kit. The core pedagogy of the kit is designed around problem-based learning (PBL) activities, which allows students to address real lighting problems.

The cognitive “constructivist” process of PBL is used in the kit:

- Learners are presented with one or more problems and through discussion within their group, activate their prior knowledge.
- Within their group, they investigate the problem with a hands-on activity. Together they identify the problem observed. They construct a shared primary solution or set of solutions to address the issue at hand.
- After the initial teamwork, students work independently or in groups in self-directed study to research the identified issues and solutions.
- The students re-group to discuss their findings and refine their initial explanations based on what they learned.

The activities are optimized for 11-16 year olds but expandable to older and younger ages. Most can be done within a few minutes during class or after-school and as stations students rotate through or as stand-alones. For IYL, 100 QLT kits were disseminated to 32 countries, and for IAU100, 100 TotN kits will be soon sent to 50 countries.

Contributions of the Brazilian Amateur Astronomy Club Centauri for the Popularization of Astronomy in Formal and Non-Formal Spaces around the Vicinities of Itapetininga City, Sao Paulo

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Introduction to Astronomy can provide a very good scenario for dissemination of science in the society. It involves Physics, Mathematics, Biology, Chemistry and the use of advanced technology. The Amateur Astronomy Club Centauri was established in 2015 and ever since it has been successfully conducting astronomy outreach and overnight stargazing events in formal and non-formal spaces within and around the vicinities of Itapetininga city, in Sao Paulo state, Brazil. The club act in schools and universities promoting science to students outside the classroom. Theory discussions are conducted covering a broad range of different fields of science by introducing the physics of the Solar System, stars, the galaxy, the interstellar medium, geographic and astronomical coordinates, the possibility of existence of life on a far distant planet, planets and stars formation, among others. Information about what we see with the naked eye, binoculars and a telescope are provided through lectures by using the free open source planetarium Stellarium. Once the schools do not have the equipment or even funds necessary to run viewing nights, the club members assemble with their telescopes and allow the students to appreciate and observe the wonders of our Universe. The club also share their time and telescopes to engage the general public with unique astronomy experiences in squares or any other opening space which provide good conditions for stargazing. The club has currently 50 members and has inspired more than twenty thousand people through their participation in events such as lectures, meetings and astronomical observations.

Day II

Porto Planetarium – Ciência Viva Center: From Immersive Fulldome To Hands-On Laboratories

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The Porto Planetarium – Ciência Viva Center (PP-CCV) is owned by the University of Porto, but is under the management of the Center for Astronomy / Astrophysics Research of the University of Porto (CIAAUP), which fosters the Institute of Astrophysics and Space Sciences (IA), the largest astronomy research unit in Portugal. Given the mission established in its bylaws, CIAAUP, and therefore PP-CCV, promotes science dissemination, science communication and astronomy teaching. As such, since its creation, the PP-CCV has promoted astronomy and science outreach through a diverse program that has evolved significantly over the years. One of the most significant changes in the educational program was the creation and implementation of hands-on laboratories that enrich the traditional fulldome planetarium shows. This was accomplished by envisioning activities which explore the school's essential learning guidelines in a more didactic way, rendering hands-on laboratories and planetarium sessions complementary in every school level. At the same time, a follow-up service was implemented, from the moment the teacher chooses one of the didactic sequences, until it is implemented in their formal education contexts. This contribution presents one of the components of an ongoing research which envisioned, developed, implemented and evaluated an educational program for the PP-CCV since 2016, and continues as an educational program, available in the current school year. This preliminary data analysis already seems to indicate that the hands-on laboratories, based on problem solving through interdisciplinarity learning strategies, are not only feasible, but also facilitate the processes of formal education.

Astronomy with Robotic Telescopes

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I will present examples of projects completed by students and teachers using the Faulkes Telescope Project and the National School's Observatory. Both projects provide 2-metre telescope access as well as supporting material on all aspects of astronomy, in particular creating light-curves of variable stars and supernovae and colour-magnitude diagrams of open clusters.

CLEA, a French pro-am initiative to foster astronomy education

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The Comité de Liaison Enseignants et Astronomes (CLEA) is a French non-profit and non-governmental association that fosters astronomy education mainly through training sessions in various regions of France, a yearly summer school and the publication of a quarterly magazine; all those mainly targeting primary and secondary teachers. Most of the members of the association are indeed primary and secondary teachers but also educators and professional astronomers. This presentation will present the organisation of the association, review the actions that CLEA has carried out for more than 40 years and the didactic methods that we promote.

Using Factor analysis of drawings to investigate students' mental models about seasons

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This study presents a new technique to investigate students' mental models about familiar astronomical phenomena using students generated drawings as data. In particular, we investigate the reliability of exploratory factor analysis to bring out mental models underlying students' drawings of seasonal changes. We analyzed 470 drawings made by 8th – 9th grade students who had received prior curricular instruction about seasons. To apply exploratory factor analysis, we first identified the relevant graphical features of the drawings, then we grouped these features via principal axis factoring. The resulting 4-factor solution explains 57% of the data variance. Two more models were introduced to account for drawings that could not be assigned to any emerging factors. Pictorial models of seasonal changes were then compared to written explanations and responses to a true/false and multiple-choice questionnaire. Results indicate that students' drawings, explanations and responses to the questionnaire are coherent. Hence, exploratory factor analysis can be considered a reliable technique to elicit mental models of seasonal changes. Our findings also show that students adopt textbook images as the cultural reference to represent their mental models. Consequently, visual representations adopted in teaching practice may influence students' ideas about seasons. Implications for research and teaching about astronomy are discussed.

Live show production

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In this poster, we will discuss the main challenges and solutions for the scenarios themes, scenario, team management, marketing materials, team rehearsals. We will

showcase examples of different formats of live planetarium shows. Moreover, we would like to initiate a discussion on how to make live shows transferable to other planetariums. Our aim is to list core/common items for the live show and how the live shows can be produced with different organizational environments.

Strategies for Implementing an Online Professional Development Experience: AWB's Building on the Eclipse Program

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Astronomers Without Borders “Building on the Eclipse Education Program” explored how to impact science identity, attitudes towards STEM and inspire audiences to explore careers in STEM. Inspired by a total solar eclipse, educators and scientists were brought together in a sustained online community of practice to support one another in learning about the Sun and light after audiences were inspired by the 2017 Solar Eclipse. The program was rebooted in Spring 2018 and continued to collect and analyzed data in an attempt to collect information on audiences for the next US total solar eclipse in 2024. Several best practice strategies were used in the design of the program. This session will explore the design of the program, the successes and challenges during implementation and evaluation, and our future plans for the effort.

FRONTIERS – Science in Schools

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Scientific literacy, so important in modern society, starts with science education. One of the most common weaknesses in school curricula is the lack of modern science. It is crucial that students understand the state of the art, the ultimate scientific discoveries and where science is heading. The Erasmus project “Frontiers: Bringing Nobel Prize Physics in the Classroom” brings current trends in physics to the hands of students in a user-friendly and effective way, while integrating the school curriculum. As part of the outcome of this project, a series of experiments are being prepared that will engage students in a unique experience of working with real data and re-discovering, for example, gravitational waves, black holes, the Sun, and exoplanets. These demonstrators, enriched with online tools and web-interactive educational material, will fully introduce the scientific methodology in school science education. Equally relevant is the fact that it will offer important professional development opportunities for teachers. The consortium is composed of experts in several cutting edge research and education institutions. A virtual learning community of educators and researchers will support collaborative learning activities. The monitorization of the FRONTIERS demonstrators will provide feedback for the take-up of such interventions in different countries. This poster will present the project FRONTIERS and its demonstrators.

Astronomy education at Székely Mikó High School

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Since there is no astronomical theme in the Romanian physics curriculum, I try to teach different topics during physics lessons. Mechanics, thermodynamics or optics can be used to introduce the interesting phenomena of astronomy, by applying different methods. I would like to show some of these ideas that I have successfully applied in last school years.

- Studying sunspots the Sun’s rotation period could be determined with the SOHO database or the “Debrecen Photoheliographic Data”. From these databases, we download 10-12 images of the Sun taken by the SOHO satellite during a few days on specified time and we process the collected data.
- We learn the basic concept of space weather and its effects on the Earth.
- Students determine the diameter of the Moon craters by photographic method and with Aladin software. They model the birth of Moon impact craters with collision experiments.
- Secondary school students build a mini satellite to determine the atmosphere components by Arduino measurements.

- At teaching the circular motion we analyse the movement of artificial moons, their orbit and angular speed.
- When here are open school days, making telescopic observations and taking astrophotos are usually famous programs.

As I see it these methods are good practice ideas which could be used at school or extracurricular activities.

Learning of the Galaxy with the Mitaka system in classes of a junior high school

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Many pedagogical methods are available in astronomy classes today, but the effect of stereoscopy is not well known. Mitaka is software developed by the 4D2U project of NAOJ for stereoscopic (3D) visualization of the Universe in various scales with observational data as well as theoretical models (Mitaka webpage; Nemoto et al. 2014). We have studied the effect of stereoscopy on the 3rd grade (K9) students with Mitaka, in the Sakaide Junior High School attached to the Faculty of Education, Kagawa University. The post-test after the classes for the comprehension of the Galaxy did not show statistically significant difference between with using and without using Mitaka. For example, we asked about the position of the Solar System within the Galaxy. However, we did find that the students increased their interest in the Universe significantly after using the Mitaka system. In this presentation, we show our results and discuss the effect of the stereoscopy with Mitaka.

Solar X-Ray Flare Monitoring for Upper Grade High School Education

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The influence of solar X-ray radiation on terrestrial radio communication was found in the early 20ies century. But it was not understood immediatly. Radio communication was a challenging topic back then, and became quickly a topic taught in science classes at school. Half a century later – with the start of the space age – it became evident, that the study of Earth’s upper atmosphere was solving this question. Solar and other cosmic radiation is responsible for the condition of the ionosphere and the cause of black-outs in long range radio communication. Today, most of the ionospheric very long frequency (VLF) radio propagation phenomena are known and presumably almost completely understood, though it stays a challenging topic listening to the ionospheric disturbances caused by our Sun. The recent development of low-cost software defined radio wave receivers (SDRs) are an on-going process and opens many new opportunities for applications in people’s daily lives and in education. Furthermore, monitoring of Earth’s lower ionosphere by utilizing VLF monitors, which are based on SDR technology, it offers new indirect insights into what happens on the Sun. Therefore, one aim of this presentation is to reach out to an educator community and to offer the InFlaMo project (www.inflamo.org) and its data for educational purposes. The other aim is to enlarge the network of ground based multichannel SDR-receivers. With this rather inexpensive method monitoring the state of the ionosphere and recording the appearance of solar X-rax flares can be made available for class-room usage.

Measuring students’ understanding of apparent motion of the Sun and stars

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In Flanders, many schools visit a planetarium in the context of cosmography lessons. The Brussels Planetarium e.g. offers a dedicated educational program for secondary schools that is aligned with the national curriculum standards. As one of the main assets of a planetarium is to visualise the night sky in a full dome projection, it might be a powerful tool to enhance student learning, given that research shows that some astronomical concepts are difficult to understand. However, although planetariums have a long history in supporting astronomy interest, it is not clear whether and how

a school trip to the planetarium contributes to effective learning of astronomical concepts. We set up a project that aims at understanding to what extent the unique planetarium projection supports concept learning. We focus on selected topics that are part of the curriculum standards: similarities and differences between the apparent motion of the Sun and stars. For these topics, we designed a test instrument consisting of 14 items. The initial version of the instrument has been validated with both secondary school and university students. Results of this pilot test gave input to optimize the instrument in order to include it in future research, both in the Planetarium in Brussels and elsewhere. In the presentation, we will explain the design of the instrument and discuss some findings of the pilot test.

The determination of the size of Moon using lunar eclipse photos

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The Universe is one of the most attractive topics for people. Neverending questions about the Universe have led us to think how it would be possible to implement astronomy in the education process. The slovak state education program for physics does not contain topics from astronomy. In the education process pupils learn about Solar System, Earth's rotation and movement of the Earth around the Sun on the age level 8-10 years in biology lessons. One way how to implement astronomy themes in the education process is to include astronomy in mathematics lessons. In our contribution we present activity: The determination of the size of Moon using lunar eclipse photos. The idea of the proposed activity is based on the original concept of Earth's shadow observation during lunar eclipse proposed by ancient Greeks. The study of the photos taken during lunar eclipse enables to find how big is the Earth's shadow comparing with the Moon and further determine the dimensions of the Moon. We recommend to include this activity in the mathematics lessons in part relating circle defined three points at primary school. The application of already known mathematical procedures and also constructive approach are needed to solve it properly. The benefits of this activity is the connection of mathematics with astronomy, the application of mathematical procedures in the context of astronomy and gaining new information about the Moon.

Continuing Professional Development for primary school teachers on astronomy and space science in Austria within the framework of the ESA ESERO network

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In 2016, the Austrian ESERO Office (European Space Education Resource Office) was opened at the Ars Electronica Center in Linz. One of the main tasks is to teach astronomy and space science to primary school teachers. The mediation takes place primarily in the form of Continuing Professional Development (CPD) training courses for teachers, which are offered at the teacher training colleges in Austria. The course “From the Face of Mars to the Black Hole” and related materials were developed for the primary school. The course consists of two parts, one part always taking place at the teacher training colleges, the second part at nearby educational institutions such as museums or planetariums. The concept is based on the principle of research-based learning and is developed in cooperation with the Competence Centre for Natural Sciences and Mathematics at the University of Education in Vienna. The lecture reports on the creation of the concept, the development of the materials as well as on the experiences gained during the training courses themselves, which could be made during the first three years within the framework of ESERO Austria. For more information see the ESERO website in Austria: <https://ars.electronica.art/esero/de/teacher-training/>

A Light Pollution Simulator

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In the framework of the Dark Skies Rangers project, we have developed a light pollution simulator aimed at demonstrating the impact of artificial light on the observation of the night sky. The simulator illustrates a nocturnal countryside scenery, with a house on one side, and a tree on top of a hill on the other side. Several stars of different brightnesses and the Moon can be seen in the night sky. The user is able to adjust up to seven exterior lighting fixtures in the pathway that separates the house and the hill. The lamps can have different configurations, depending on the type of shielding and height of the lamp post. Regarding the shielding, the lamp can be (a) unshielded, allowing the light to be sent upwards and hence strongly affecting the visibility of the stars, (b) half-shielded, sending light sideways and downwards, partially affecting the observation of the night sky, and (c) fully-shielded, only allowing light to be sent downwards and thus not affecting the observation of the celestial bodies. There are two possible heights for the lamps to demonstrate that in some cases small lamps are enough to illuminate the path. The simulator was developed in JavaScript using React/Redux. It is open source and freely available as a lab for the Graasp digital education platform. It is intended to raise awareness of the importance of using efficient illuminating systems and preserving the night sky and, thus, to be used as a resource for education and outreach.

Using constellations to infer the shape of the Earth

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I will present an education activity based on Inquiry and large-scale collaborative work, developed to bring students to infer the true shape of the Earth by observing constellations and by sharing their data with other colleagues living in different latitudes. The activity follows the canonical steps of the Inquiry-based Learning methodology. While going through each of the Inquiry phases, students apply the scientific method to learn the shape of our planet: they have to make observations of the night sky, to create a long term strategy to observe at least one constellation throughout the academic year, to register data, to perform measurements and calculations, to share them in the GlobalLab platform, to draw conclusions, and to discuss the results with classmates and colleagues living in other latitudes (and possibly other countries) carrying out the same activity. Students are encouraged to test different approaches and models that can potentially explain their observations. No direct conclusions are given at any stage. An important part of the activity focus on the contextualisation of the leaning process, by awakening in students the curiosity to understand how their findings fit in the common knowledge of the community surrounding them. This allows students to develop critical thinking, and the capacity of living with different perspectives and points of view. I will describe the Inquiry process, focusing mainly on the orientation and conceptualisation phases, on tips for the teacher and on useful tools and resources for a successful implementation of the activity.

The EuroPlanet webinars on planetary research

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Since October 2016, the EuroPlanet Society, NUCLIO and GTTP have organised a series of monthly online webinars dedicated to planetary research. The goal is to bring researchers, students and enthusiasts together in an one-hour live session dedicated to the exploration of our Solar System and beyond. These online presentations are an authentic and exciting way to experience cutting-edge science and interact with the researchers involved, sometimes directly from their laboratories and field missions. The webinars centre around a 40 minute presentation from an invited researcher on a relevant topic that is accessible to a diverse audience, including secondary school students. A presenter introduces the speaker and subject, and hosts a Q&A session from the live viewers at the end. The webinars are broadcast using the Zoom video-conferencing platform, and simultaneously live streamed on Youtube. After the webinars, an edited version is made available on the Europlanet YouTube Channel. So far there have been nineteen webinars, with more than 600 planetology enthusiasts and some 50 school classes, several of which are regular attendees, participating live, with a further 2000 views on demand. Based on these numbers and the feedback gained through our social media, we will present relevant metrics illustrating the impact of the webinars in raising awareness amongst students and general public for the importance of planetary research in our everyday life.

Digital Technologies as didactic resource for Science Teaching in the last year of Elementary School of Public Schools of Brazil

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The technological transformations in the last decades have asked the teachers a new look at how to teach and why to teach, since it is necessary that the knowledge be transformed to connect with the daily life of the students. So the school must also adapt to this new reality. This work aimed to verify the insertion of digital technologies in the daily life of the students of public schools of the state school system in Brazil. Four schools were chosen for the research, two of which were located in Divinópolis MG, a city in the interior of Minas Gerais, and two located in the outskirts of Greater São Paulo. In the research the students answered a questionnaire with six objective and discursive questions. From the analysis of the answers given it was concluded that more than seventy percent of the students surveyed use the smartphone as the main tool associated with digital technologies. Other options like tablets or desktop computers were little chosen. When we asked about the use of digital technologies by the teacher during science classes, there were very different answers. At school A, 30 students stated that the science teacher does not use digital technologies in their classrooms. In school B, in the same city the result was the opposite, because all 36 students said the teachers' daily use of technologies. At school C, 22 students said that they did not use technologies in their classes while at school D, only 17 students made this statement.

Day III

Astronomy teaching and outreach activities at Paris Observatory

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Through a range of teaching and outreach activities, the 100+ teacher-researchers of Paris Observatory address a variety of audiences. This includes primary and secondary school teachers, with on-site presentations by astronomers in classes. A range of diploma courses is also offered by the Observatory. They are open to a wide audience (students, professionals, amateurs), either through traditional classroom training (with possible online video attendance) and a distance tutoring scheme. Classical formations at the license, master and doctorate level are also in place. I will focus my presentation on the innovative pedagogical approaches that were developed in the various formations of the teaching department.

Practices of outreach in Astrobiology for presentation as a Poster

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Interest in the existence of aliens has always been high. A large number of exoplanets have been found, and it is now an age when a life in the Universe can be scientifically studied. “Astrobiology” is a new research field that search for places in the Universe that can accommodate life, in addition the existence of life itself, and discuss the origin and the evolution of life without solely on the Earth. It is not only astronomy and biology, it is a multidisciplinary research field such as planetary science, Earth science, molecular science, life science and engineering. While many spacecrafts and various aliens are depicted in science fiction movies, it is not well known actual Astrobiology research. I will introduce activities to instill in society the research field of “Astrobiology” in Japan.

Astronomy in Salzburg

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The opening of the observatory (<https://www.hausdernatur.at/de/allgemeine-informationen.html>) Vega close to Salzburg will probably have a positive impact on the curriculum of the future physics teachers. The author of this contribution belongs to the group of volunteers who take care of the new observatory and also teaches at the University of Salzburg to future physics teachers. Thanks to a contact with ESA, the author has also developed a teaching class on the project ASTRO PI (<https://astro-pi.org/>). These activities turned on the interest of the students, and this interest ended up in some interesting bachelor and one master-degree thesis, all concentrated on “bringing astronomy to the schools“. One bachelor-thesis focusses on the use of a DSLR camera together with the Star Analyser 100 diffraction grating to identify the spectral class of some stars belonging to the main sequence. Another bachelor thesis focusses on the analemma using the ASTRO PI hardware ho host a WEB Server that shows the “construction” of an analemma taking periodically a picture of the Sun at noon and overlying the acquired pictures. One bachelor thesis which should end up in a master thesis is devoted to the prograde and retrograde motion of the planets. For this work we will work with a planetarium software and will also consider their historical importance and the mathematical description. Human orrerys as a didactical tool (embodied learning) will also be considered.

Do students attending also informal lectures have a better astronomical knowledge? Exploring the 10-13 age comparing school education and informal lectures

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Kids receive most of their astronomical knowledge through three fonts: formal education (school), informal education (laboratories, scientific festivals and other out-school activities) and media (TV documentaries). In the first case, students learn astronomy from certified fonts (school books and others teaching tools) and their knowledge is verified by teachers. However, for first grade schools, deep competence of teachers in specific topics of science is not usually requested. In the second case, the situation is less homogeneous. Informal education is located in scientific structures (Universities, Planetarium, Observatories), scientific festivals or dedicated structures for science outreach and it is lead by researchers (with little if any educational preparation) or by members of associations for scientific popularization. Moreover, an important source of informal education comes from the media and internet, where one can find numerous science outreach blogs, facebook and web pages. The outcome of this sources of information in terms of misconceptions has not been investigated in detail yet at least in Europe. This work is a quantitative study regarding the knowledge of astronomy concepts in students aged 10-13. The aim of this work is 1) to explore the astronomy knowledge and misconceptions in students in the age range 10-13 and 2) to compare two types of students: those attending only regular school lessons and those attending also informal education. We tested the hypothesis that these latter students are more motivated to go deeply in their astronomical education and should have, at least in principle, a more precise astronomical knowledge. We proposed questionnaires with questions about Black Holes, Star life, Seasons, Moon phases and others astronomical concepts. Data were collected from 2014 to 2017 and the final sample consisted of 1600 students. The results will be used for make recommendations for outreachers.

Destinazione LUNA – Destination MOON

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In this talk we highlight the outreach activities carried on in Bologna celebrating the 50th anniversary of the man on the Moon and the 20th year of INAF (Italian National Institute for Astrophysics) by INAF itself, Cineteca di Bologna and Hamelin. This occasion was the chance to build a broad and diverse team of experts in many fields (astrophysics, pedagogy, picture books, cinema) with the aim of bringing the Moon very close to Bologna's people. We want to talk, play and engage citizens (young and adults) reflecting and enjoying different way to see the Moon and the space exploration. We design, test and operate workshops for kids (4-9 year old), a cineclub and mini-conferences for teens with a focus on the gender dimension in collaboration with schools and "Girls code it Better", open air movie nights during the film festival "Sotto le stelle del Cinema 2019", picture book readings and discussions from september 2018 to september 2019 through a full year of MOON. We also participate, as INAF, to PLAY – the games festival with this year theme "Race for Space", exploring constructivist pedagogy in the pursuit of playfulness as a safe environment to explore new ideas and mitigate self prejudice. As an outcome of this year-long activity we will publish a book with dedicated resources (bibliography, filmography, ludography) for young adults, teachers and educators.

“Officina degli errori” a teacher training experience on STEM education

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With “officina degli errori” – a teacher training offered by INAF to primary school teacher during the school year 2018/2019 – we added another little tile to our work: desi-

gning, promoting and delivering hands-on, self-directed and playful activities to engage children with STEM. Also in this case we used a constructionist approach: knowledge is not simply transmitted from teacher to learner, but actively constructed by the mind (and the hands) of the learner and the students are more likely to develop new insights and understandings while actively engaged in making an external artifact (Papert 1980). This method supports the construction of knowledge within the context of building personally meaningful artifacts, and the more self-directed the work is the more meaningful the learning becomes. Tinkering activities are based on the idea that a playful but structured activities can lead to a self-directed approach towards knowledge that frees the kids and let them play with STEM concepts in a setting that won't stigmatize mistakes and that promotes peer tutoring and collaborative approaches. We also see this approach as a metaphor for the scientific research where new concepts emerge in a collaborative environment where error is valued as a necessary means towards new outcomes. We found through activities held in Primary School that – even at this early stage of education – kids already have a deep and strong bias towards science, maths and technology in general. This keeps them from being able to freely experiment in such fields. This image of one's self can be changed only in the frame of a new approach to STEM (and education in general) that breaks some of the basic prejudices about talents and subjects. We believe a deep and profound engaging of teachers is needed to engage the pupils deeply and long lasting. This year long activity comprehended 3 sessions with teachers, 1 tinkering workshop for each class where the teacher can experiment and learn facilitation in a "safe" environment, 1 tinkering workshop for each class where teachers mentor their colleagues, several tinkering sessions in class where they can experiment with a kit provided by INAF and Museo del Patrimonio Industriale and test this new way of teaching STEM in their usual environment, finally a session with the collection and the analysis of the all the experiences. We believe this training was extremely successful not just because we passed some STEM literacy but because we believe we changed a bit the teachers' pedagogical perspective on STEM learning and inclusion in STEM with a focus on gender and socio-economic condition. We hope in the future to evolve this teacher training and to allow more teachers to participate.

Development of a sustainable system for education through an astronomy club

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An astronomy club in Chiyoda Ward Kudan Secondary School holds stargazing events for elementary school students once a month. At this event, though astronomers give a lecture at first, later activities such as a planisphere workshop, stargazing with telescopes are all performed by the students of the astronomy club. The astrono-

mers taught the students about astronomy when we started to hold the event, but now they are studying independently and deepening their knowledge. Their club activities have been an opportunity for the students to study independently. Moreover, they have interested in astronomical research. Under the guidance of the astronomers, they have advanced their research and made presentations at the junior session of The Astronomical Society of Japan. Recently, some of the students who participated in the stargazing events join the astronomy club. Furthermore, graduates from Kudan secondary school have been teaching to the students. The graduates have improved their teaching skills through astronomy club activities. Developing such activities as a sustainable system of astronomy education will be an issue in the future.

AstroElves: a project of astronomy outdoor education

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The term 'outdoor education' is mainly used to refer to a range of organized activities that take place in predominantly outdoor environments. In our conception, this term should be applied as a synonymous of "education outside the classroom", a change of perspective/points of view, which leads us to perceive external spaces as potential places for learning where to live practical and experiential experiences. In this sense, the outdoor education assumes a pedagogical line that looks outer space as the context of learning process, regardless of the nature of the proposed content. Outdoor education activities are by nature pleasing by students of any age but in particular have been found more beneficial to those students who find classroom learning more challenging. In the framework of a larger inclusion project, INAF-Cagliari Astronomical Observatory has been experimenting for about a year with an outdoor education project called AstroElves. This project stems from the collaboration with a Sardinian Cultural Association ("Punti di Vista"), very active in proposing outdoor education projects and environmental awareness activities. The AstroElves project is a two days outdoor campus dedicated to the study of the sky and the discovery of uncontaminated places from which to observe the starry sky. The main objective of the project is to show the intimate connection between the natural environment and the sky and to discover the special role played by astronomy in everyday life. During the day the participants could explore beautiful places, woods and hills far from the city lights, discuss about light pollution, and "play" with the Sun, experimenting its apparent movement in the sky, discovering the concept of "true" noon and building a simple solar meridian; the night instead they could observe stars and constellations guided by professional and amateur astronomers. We here present the organization and the results of the first two AstroElves camps, carried out in April 2018 in the beautiful area of Gerrei surrounding the Sardinia Radio Telescope (SRT) and in April 2019 at the Monte Armidda, close to Lanusei.

Angles – What do they tell us about the Earth and the celestial motions?

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I am a science outreach professional, engaged in astronomy outreach since 2004. I am working for Astronomy and School Outreach at Inter-University Centre for Astronomy and Astrophysics, Pune, India since 2014. I am involved in designing and conducting teachers training programmes along with other outreach programmes for students and the public. Being an astronomy educator, I am looking forward to gaining knowledge of astronomy education and research worldwide. This will be helpful in collaborating with people sharing the same interest and similar profession around the globe. However, my contract with the institute does not support travel for non-permanent employees. If given an opportunity, I will be conducting a workshop on some hands-on astronomy activities. Apart from this, I would also like to share some hands-on activities for daytime astronomy or classroom activities we conduct here for students and teachers (these are developed considering the school curriculum in India). I would also be happy to be an active part of any outreach activity (if any) during or around the workshop for local schools or the public.

Astronomy Education in Italy: the Italian National Institute of Astrophysics strategy

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In the last 20 years, astrophysicists changed our vision of the Universe: countless extrasolar planets, dark energy, black holes, gravitational waves, liquid water on

Mars, ocean on Europe icy jets from Enceladus. Astronomical results demonstrated they interest people as medicine does and they are a real fortune for television and new media. In the same period in Italy, astrophysics seems to be more and more marginalised as a specific discipline at school. To contrast this tendency, the Italian National Institute of Astrophysics (INAF) runs tens of thousands of educational activities for 12-18 year old students, with high success and appreciation, in collaboration with the Italian Astronomical Society (SAIt). After having collected the needs of teachers at national level, we planned an overall strategy to meet their requests. We developed EBL activities, gamification, tinkering, coding, making, critical thinking exercises, citizen science environments for schools, thanks for example to the Virtual Observatory or other scientific programs educational activities. Part of this strategy was the delivering of astroEDU in Italian, which occurred in September 2017 when astroEDU/it became its first non-English version. Thanks to an overall approach and these tools, in our country, Astronomy has now the chance to display its potential as one of the more powerful tools to engage students and teachers, thanks to its multidisciplinary and inclusive nature, which is actually far beyond the definition of STEAM.

New interactive astronomy course for high school students and teachers

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Here we present the idea, structure and content of a new interactive astronomy course developed for Moscow high school students and their teachers. The course consists of 35 lessons uploaded to the Moscow Electronic School – an online educational platform which is supposed to become a new standard for Moscow state schools. All scenarios for the lessons were prepared by professional scientists (astronomers, geophysicists, space engineers etc.) and educators recruited around the world. The main goal of the course is to present a contemporary view of the Universe and the basics of the method of scientific research. Also, students will be provided by direct speech from today's astronomers and learn about connections between the science and various parts of everyday life. Each lesson of the course contains a number of more or less independent and updatable components: a review of up-to-date astronomical news (supported by Russian scientific media), one unique animated podcast, a set of interactive exercises, a commentary from an expert, homework tasks and supplementary materials. Thus, each lesson, in fact, is a construction kit providing a teacher with the educational stuff for his/her astronomical classes. At the same time, each lesson can also be used autonomously without a teacher at all. The latter is particularly important since the Moscow state educational system suffers from the lack of qualified teachers of astronomy. Thus, we believe that the adopted "construction kit" approach can be widely used within the worldwide astronomical education.

An Art + Science approach in the context of Astronomy Education

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Both in their self and public images, artist and scientists are often set in opposition: while one seems to seek no answer the other seeks only the “correct one”. However, artists and scientists, share two fundamental talents: their ability of seeking out patterns and of sensitizing other to what they perceive. In their own characteristic mode, art and science allow people to (re)consider unknown or ignored aspects of the Universe that surrounds them (F. Oppenheimer, 1972). Despite this similarity, within educational discourse, art is rarely used as a tool to expand the engagement and understanding of the natural world, being relegated largely to a domain of technique and production (McDougall, Bevan & Semper, 2011). This talk presents how the spaceEU project embeds art’s creative practices and critical thinking in its education and outreach activities, bringing artists to co-create workshops, give talks and present their work within spaceEU exhibition. With its art+science approach, spaceEU invites students to identify, synthesize and represent complex and technical space contents. spaceEU is a EU funded project that builds on the legacy of Space Awareness and Universe Awareness to deliver an exciting Space Outreach and Education programme to capture the interest of young people in STEAM fields and encourage them to choose space-related careers.

spaceEU: fostering a young creative and Inclusive Space Community

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Led by Leiden University, spaceEU implements an exciting Space Outreach and Education programme to capture the interest of young people in STEAM fields and encourage

them to choose space-related careers. The project inspires and broadens young people's minds, develops a sense of European and global citizenship and builds long-term partnerships between people from different cultural backgrounds and countries. In this project presentation we will share the results, best practice and lessons learned so far. Led by Leiden University, spaceEU implements an exciting Space Outreach and Education programme to capture the interest of young people in STEAM fields and encourage them to choose space-related careers. The project inspires and broadens young people's minds, develops a sense of European and global citizenship and builds long-term partnerships between people from different cultural backgrounds and countries. In this project presentation we will share the results, best practice and lessons learned so far.

Developing a STEAM Mindset in Astronomy Education

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We will describe lessons learned from the recently completed National Science Foundation-sponsored project "Project STEAM: Integrating Art with Science to Build Science Identities among Girls" and the ongoing NSF project "Collaborative Research: Advancing Professional Development and Broadening Participation in Informal Science Learning via the Integration of the Science and Art of Color." These projects incorporated a STEAM mindset and identity work principles to create some guiding principles in the design and implementation of STEAM projects. In particular agentive tool use and putting the tools into the hands of the learners are key to having specific outcomes. These design principles were demonstrated in informal science education settings but also have broad applicability to classrooms. We will describe how these key lessons learned over the last 6 years can be applied to astronomy education programs. The lessons have particular relevance for programs server upper elementary and middle schools girls and that serve Native American girls.

Bring Astronomy Research to the Public / Students

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Improvement of the public scientific literacy is not only to know more about scientific knowledge, but also to understand the scientific methods and the cultivation of scientific spirit. Especially for middle school students, letting them join in scientific inquiry will help their growth and subsequent development. Stories based on scientific research is a good way to share science with the public. However, scientific research is often viewed as inscrutable by the public. How can we make astronomical science research closer to the public, especially to the students? To achieve the goal, we have been carrying out projects on the news releases, science-art exhibitions, platform for middle school students to take part in science and technology projects, astronomy course vedios, audios of interviews with scientists, STEM curriculum, etc.I will present our motivation, progresses, experiences and also unsolved problems. Looking forward to hearing more comments from you.

The role of an astronomical observatory in outreach and education: How to reach society

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Astronomical education can be performed by different actors: science museums, universities but also research centers and professional observatories that care about transmitting science to the public. The right equilibrium between research and science dissemination and education is sometimes difficult to find. Here we will show several examples of educational programs carried out at the Observatoire de la Côte d'Azur (Nice, France) that combine research and education and allow us to reach society.

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