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

Leveraging the potential of astronomy in formal education

15 – 17 November, 2022

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

Publications of the
IAU Office of Astronomy for Education

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

The following is a collection of summaries from the 4th Shaw-IAU workshop on Astronomy for Education held 15 – 17 November, 2022 as a virtual event. The workshop was organised by the IAU Office of Astronomy for Education. More details can be found on: `https://astro4edu.org/shaw-iau/4th-shaw-iau-workshop/`.

The IAU Office of Astronomy for Education (OAE) is hosted at Haus der Astronomie (HdA), managed by the Max Planck Institute for Astronomy. The OAE's mission is to support and coordinate astronomy education by astronomy researchers and educators, aimed at primary or secondary schools worldwide. HdA's hosting the OAE was made possible through the support of the German foundations Klaus Tschira Stiftung and Carl-Zeiss-Stiftung. The Shaw-IAU Workshops on Astronomy for Education are funded by the Shaw Prize Foundation.

The OAE is supported by a growing network of OAE Centers and OAE Nodes, collaborating to lead global projects developed within the network. The OAE Centers and Nodes are: the OAE Center China–Nanjing, hosted by the Beijing Planetarium (BJP); the OAE Center Cyprus, hosted by Cyprus Space Exploration Organization (CSEO); the OAE Center Egypt, hosted by the National Research Institute of Astronomy and Geophysics (NRIAG); the OAE Center India, hosted by the Inter-University Centre for Astronomy and Astrophysics (IUCAA); the OAE Center Italy, hosted by the National Institute for Astrophysics (INAF); the OAE Node Republic of Korea, hosted by the Korean Astronomical Society (KAS); OAE Node France at CY Cergy Paris University hosted by CY Cergy Paris University; and the OAE Node Nepal, hosted by the Nepal Astronomical Society (NASO).

IAU

OAE

THE SHAW PRIZE 邵逸夫獎

Foreword

4th Shaw-IAU Workshop on Astronomy for Education

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

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

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

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

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

Contents

Organising Committees

Local Organising Committee:
Asmita Bhandare, Ankit Bhandari, Sigrid Brummer, Niall Deacon, Natalie Fischer, Esther Kolar, Anna Ladu, Tshiamiso Makwela, Carmen Müllerthann, Eduardo Penteado, Markus Pössel, Bhavesh Rajpoot, Saeed Salimpour, Gwen Sanderson, Rebecca Sanderson, Anna Sippel, Tilen Zupan.

Scientific Advisory Committee:
Mohamad Alassiry, Ali Al-Edhari, Mashhoor Al-Wardat, Asmita Bhandare, Suresh Bhattarai, Estelle Blanquet, Silvia Casu, Ahmed Chaalan, Merryn Cole, Hassane Darhmaoui, Niall Deacon, Rosan Doran, Federica Duras, Livia Giacomini, Edward Gomez, Violette Impellizzeri, Jacob Tolno Israel, Li Jian, Cui Jie, Awni M. Khasawneh, Colm Larkin, Hamid El Naimiy, Tshiamiso Makwela, Giulio Mazzolo, Farseem Mohammedy, Magda Moheb, El-Fady Morcos, Surhud More, Thomson Mucavela, Assia Nechache, Li Peng, Eduardo Penteado, Frederic Pitout, Markus Pössel, Gilles Remy, Sara Ricciardi, Emmanuel Rollinde, Somaya Saad, Gwen Sanderson, Stefano Sandrelli, Hyunjin Shim, Anna Sippel, Jungjoo Sohn, Abdelhafidh Teyehi, Alessandra Zanazzi, Jin Zhu.

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

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

INSIGHTS FROM ASTRONOMY EDUCATION RESEARCH

Astronomy Education Research on the Role of Astronomy in Schools

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

Session overview

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

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

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

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

Developing Transferable Spatial Thinking and Vocabulary Skills Through Astronomy Education

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

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

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

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

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

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

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

References:

- Bodner, G. M., & Guay, R. B. (1997). The Purdue visualisation of rotations test. The chemical educator, 2(4), 1-17.

- Cole, M., Cohen, C., Wilhelm, J., & Lindell, R. (2018). Spatial thinking in astronomy education research. Physical Review Physics Education Research, 14(1), 010139.

- Hegarty, M. (2014). Spatial thinking in undergraduate science education. Spatial Cognition & Computation, 14(2), 142-167.

- Kell, H. J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2013). Creativity and technical innovation: Spatial ability’s unique role. Psychological science, 24(9), 1831-1836.

- Lindell, R. S., & Olsen, J. P. (2002, August). Developing the lunar phases concept inventory. In Proceedings of the 2002 Physics Education Research Conference. New York: PERC Publishing.

- Pribyl, J. R., & Bodner, G. M. (1987). Spatial ability and its role in organic chemistry: A study of four organic courses. Journal of research in science teaching, 24(3), 229-240.

- Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why, and how?. In Psychology of learning and motivation (Vol. 57, pp. 147-181). Academic Press.

- Wilhelm, J., Jackson, C., Sullivan, A., & Wilhelm, R. (2013). Examining differences between preteen groups’ spatial-scientific understandings: A quasi-experimental study. The Journal of Educational Research, 106(5), 337-351.

- Wilhelm, J., Wilhelm, R., & Cole, M. (2019). Creating project-based STEM environments. Springer International Publishing.

Infusing Quantitative Reasoning into Introductory Astronomy and Other Science Courses

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

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

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

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

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

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

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

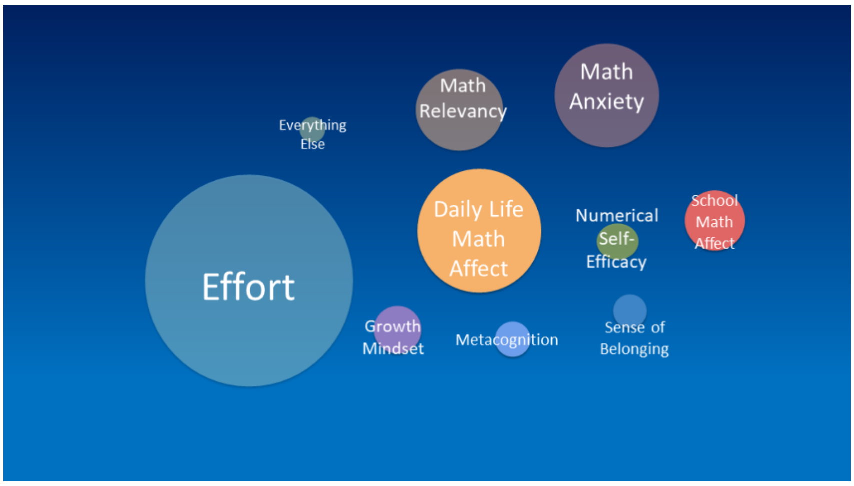

Figure 1: Revised Affective Model of Predictors for Students Quantitative Reasoning Scores

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

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

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

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

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

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

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

Acknowledgement: This material is based upon work supported by the National Science Foundation under Grant No. 2044372. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References:

- Follette, K. B., McCarthy, D. W., Dokter, E., Buxner, S., & Prather, E. (2015). The Quantitative Reasoning for College Science (QuaRCS) Assessment, 1: Development and Validation. Numeracy: Advancing Education in Quantitative Literacy, 8(2).

- Follette, K., Buxner, S., Dokter, E., McCarthy, D., Vezino, B., Brock, L., & Prather, E. (2017). The Quantitative Reasoning for College Science (QuaRCS) Assessment 2: Demographic, Academic and Attitudinal Variables as Predictors of Quantitative Ability. Numeracy: Advancing Education in Quantitative Literacy, 10(1).

Astronomy Teacher Training Programs in Chile

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References:

1. Catanzaro, M. (2014). Chile: Upward trajectory. Nature, 510, 204–205.

2. Marinovic, F. (2016). Estudio astronomía y marca país: una mirada desde la opinión pública chilena [Astronomy and country trademark study: a view from Chilean public opinion]. Fundación Imagen de Chile.

3. OECD (2016). PISA 2015 results: excellence and equity in education. Volume I. OECD Publishing.

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

5. Rodrigues, L., Montenegro, M., & Meneses, A. (2022). Mapping the astronomy content knowledge of Chilean in-service teachers. [Manuscript submitted for publication].

6. Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. Learning Policy Institute.

7. Desimone, L. M. (2009). Improving impact studies of teachers' professional development: toward better conceptualisations and measures. Educational Researcher, 38(3), 181–199.

8. Pompea, S. M., & Russo, P. (2020). Astronomers engaging with the education ecosystem: a best-evidence synthesis. Annual Review of Astronomy and Astrophysics, 58, 313-361

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

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

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

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

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

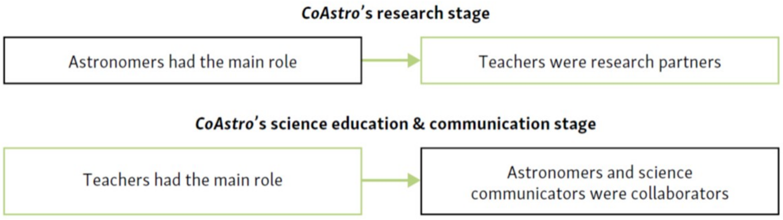

Figure 1: CoAstro's stages [7]

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

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

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

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

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

Table 1: AQ pretest and posttest overall results.

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

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

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

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

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

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

References:

1. Becker-Klein, R., K. Peterman, and C. Stylinski, Embedded assessment as an essential method for understanding public engagement in citizen science. Citizen Science: Theory and Practice, 2016. 1(1): p. 1-6.

2. Marshall, P.J., C.J. Lintott, and L.N. Fletcher, Ideas for Citizen Science in Astronomy. Annual Review of Astronomy and Astrophysics, 2015. 53: p. 247-278.

3. Price, C.A. and H.S. Lee, Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. Journal of Research in Science Teaching, 2013. 50(7): p. 773-801.

4. Riesch, H. and C. Potter, Citizen science as seen by scientists: Methodological, epistemological and ethical dimensions. Public understanding of science, 2014. 23(1): p. 107-120.

5. Bressoux, P., As pesquisas sobre o efeito-escola e o efeito-professor. Educação em revista, 2003. 38: p. 17-88.

6. da Fonseca, J.L.S., Pesquisas sobre o efeito escola: uma contribuição para a qualidade da educação no Brasil. Revista Contemporânea de Educação, 2011. 2(4).

7. Costa, I.A., C.S. Lopes Morais, and M.J. Pires Fernandes Garcia Monteiro, La ciencia ciudadana a través de la escuela: La importancia de las relaciones interpersonales. Cuadernos.info, 2022(52): p. 113-135.

8. Zeilik, M., et al., Conceptual astronomy: A novel model for teaching postsecondary science courses. American Journal of Physics, 1997. 65(10): p. 987-996.

9. Deming, G.L., Results from the Astronomy Diagnostic Test national project. Astronomy Education Review, 2002. 1(1): p. 52-57.

10. Turkoglu, O., et al., On pre-service science teachers preexisting knowledge levels about basic astronomy concepts. International Journal of Physical Sciences, 2009. 4(11): p. 734-739.

11. Brunsell, E. and J. Marcks, Identifying a baseline for teachers' astronomy content knowledge. Astronomy Education Review, 2005. 2(3): p. 38-46.

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

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

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

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

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

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

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

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

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

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

Students' International Network for Astronomy

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

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

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

– –

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

The main aims of this network are involving students in astronomical programs and projects, preparing a reliable structure for students around the world to meet each other using astronomy as a link, using the methods of sustainable development to teach students about the global environmental concerns and world peace, letting students make friends without any limitations and introducing their own culture, activities and feelings to each other, using astronomy and other activities to help them learn social skills such as team-working, event planning and management, cooperation and formal behaviour, and other goals that can be related to the international strategy plans.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References:

1. Aguiar, R. R. Tópicos de Astrofísica e Cosmologia: uma aplicação de Física Moderna e Contemporânea no Ensino Médio. Mestrado em Ensino de Física. Universidade de São Paulo, 5 nov. São Paulo. 2010.

2. Aguiar, R. R., Hosoume, Y. Tópicos de Astronomia, Astrofísica e cosmologia na 1^{a} série do Ensino Médio como parte integrante de um projeto curricular diferenciado de Física. Revista Latino-Americana de Educação em Astronomia. n. 25, p. 51-70. 2018.

3. Arthury, L. H. M. A Cosmologia Moderna à luz dos elementos da epistemologia de Lakatos. Dissertação de Mestrado. Universidade Federal de Santa Catarina, 6 nov. Florianópolis. 2010.

4. Bagdonas, A. H. Discutindo a natureza da ciência a partir de episódios da história da cosmologia. Dissertação de Mestrado em Ensino de Física. Universidade de São Paulo, 30 maio. São Paulo. 2011.

5. Bagdonas, A., Zanetic, J., Gurgel, I. Quem descobriu a expansão do universo? Disputas de prioridade como forma de ensinar cosmologia com uso da história e filosofia da ciência. Revista Brasileira de Ensino de Física. v. 39, n. 2, 26 jan. 2017.

6. Eriksson, Urban. Disciplinary discernment: Reading the sky in astronomy education. Physical Review Special Topics - Physics Education Research. 2019.

7. Leite, C. Formação do professor de Ciências em Astronomia: uma proposta com enfoque na espacialidade. Tese de Doutorado. Universidade de São Paulo. São Paulo. 2006.

8. Nascimento, J. O. V. Proposta de material paradidático sobre as origens do universo e da vida. Mestrado Profissional. Programa de Pós-Graduação em Astronomia. Universidade

Estadual de Feira de Santana, Agosto. Feira de Santana - Bahia. 2015.

9. Porto, C. M., Porto, M. B. D. S. M. A evolução do pensamento cosmológico e o nascimento da ciência moderna. Revista Brasileira de Ensino de Física v. 30, n. 4. 2008.

10. Sales, N. L. L. Problematizando o Ensino de Física Moderna e Contemporânea na formação continuada de professores: Análise das contribuições dos três momentos pedagógicos na construção da autonomia docente. Tese de Doutorado. Universidade de São Paulo. São Paulo. 2014.

11. Skolimoski, K. N. Cosmologia na teoria e na prática: possibilidades e limitações no ensino. Dissertação de Mestrado em Ensino de Física. Universidade de São Paulo, 31 out. São Paulo. 2014.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Research Questions:

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

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

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

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

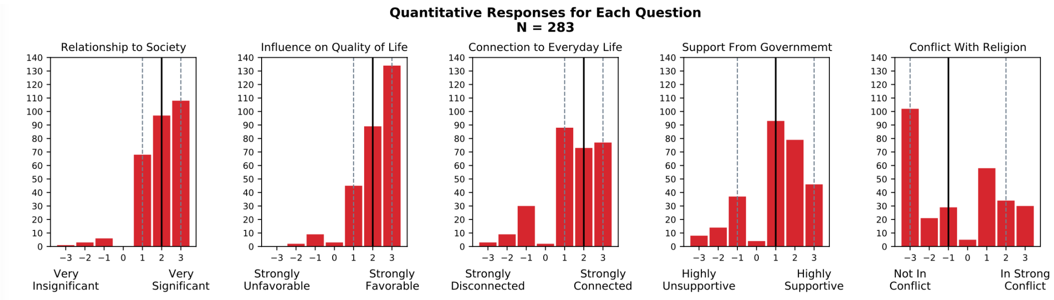

Figure 1: The distribution of quantitative responses on a -3 to +3 scale for each question. Responses on the Society, Quality of Life, Daily Life, and Government strongly skewed positive, while the Religion question has a bimodal distribution, indicating more polarised beliefs.

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

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

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

References:

- Follette, Katherine B.; McCarthy, Donald W.; Dokter, Erin; Buxner, Sanlyn; and Prather, Edward (2015) "The Quantitative Reasoning for College Science (QuaRCS) Assessment, 1: Development and Validation," Numeracy: Vol. 8: Iss. 2, Article 2. DOI: http://dx.doi.org/10.5038/1936-4660.8.2.2

- Follette, Katherine, Sanlyn Buxner, Erin Dokter, Donald McCarthy, Beau Vezino, Laci Brock, and Edward Prather. "The Quantitative Reasoning for College Science (QuaRCS) Assessment 2: Demographic, Academic and Attitudinal Variables as Predictors of Quantitative Ability." Numeracy 10, Iss. 1 (2017): Article 5. DOI: http://dx.doi.org/10.5038/1936-4660.10.1.5

- Impey, C.D., Formanek, M., Buxner, S.R., & Wenger, M.C. (2017). Twenty-Seven Years of Tracking Undergraduate Science Knowledge and Beliefs. The Electronic Journal of Science Education, 21, 41-64.

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

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

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

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

During the International Year of Basic Sciences for Sustainable Development (IYBSSSD2022), the Romanian National Committee for Astronomy (CNRA) has launched a campaign to promote basic sciences in 167 schools all over Romania. We took this opportunity to run a research study on the role of basic sciences and in particular, astronomy plays in motivating students towards STEM and choosing STEM careers. Two surveys were administered one before and one after the activities of the campaign took place. In this study we present the results of the initial survey, administered to 1548 students, mostly from urban areas (80%), 59% girls and 41% boys. The only bias in our sample is the fact that the schools have voluntarily applied to participate in the campaign. With this initial survey we wanted to assess the current contribution of astronomy and space science in STEM education in Romania.

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

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

http://astro4edu.org

@astro4edu

IAU OFFICE OF ASTRONOMY FOR EDUCATION
OAE

THE SHAW PRIZE
邵逸夫獎

IAU