

Science communication through astronomy education: The creation, implementation, and assessment of Porto Planetarium's science education strategy

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The Porto Planetarium – Ciência Viva Center (PP-CCV) is under the scientific and operational management of the Center for Astronomy/Astrophysics Research of the University of Porto, which also hosts the Institute of Astrophysics and Space Sciences (IA), the largest astronomy research unit in Portugal. This article presents the conception, development, implementation and evaluation of PP-CCV's ongoing science education strategy, built upon two main pillars: Science Communication and Science Education. Those self-sustained pillars are interconnected, leveraging each other in a truly synergistic process. The assessment of the science education strategy was carried out through a questionnaire, participant observations and interviews. These results revealed how we can effectively connect science education and science communication using outreach structures already established in research units. However, those institutions must understand the school curricula and get to know the teacher's ecosystem. That will be the foundation for us to build upon and to move from what students should know – the prescribed curriculum – to what is scientifically relevant for them to know – the most up-to-date foundations of scientific knowledge and process. With that, we can start from science education to reach science communication by framing the curricula with the most up-to-date scientific knowledge and processes.

The context

A bit of history

Founded in 1989, the Center for Astronomy/Astrophysics Research of the University of Porto (CIAAUP) is a private, non-profit association recognised as of public utility, which has three main areas of intervention in the field of astronomy: research in astrophysics, space science, and science education and communication research, education support at all levels, from kindergarten to PhD, and public outreach.

CIAAUP was one of the first research centres in Portugal to have an outreach team to increase the general public's scientific literacy. Outreach activities began in 1990 with a portable planetarium that visits schools – an activity that continues today. So far, internal reports have indicated that more than 250,000 school children had their first contact with

basic astronomy concepts inside our inflatable dome.

The experience gained in the portable planetarium was invaluable for starting outreach activities in the Porto Planetarium – Ciência Viva Center (PP-CCV). In 1998, the PP-CCV, operated and managed by CIAAUP, opened its doors to the public. Its mission is to promote active citizenship based on scientific knowledge, promote scientific culture, and challenge the public to share and discuss novel experiences. We want to inspire and mobilise people through science. PP-CCV has an annual average turnout (pre and post-pandemic) of about 38000 visitors.

CIAAUP shares with PP-CCV an Administration and Services Unit and its Outreach Unit staff: the Executive Director (also Science Communication Group coordinator at the Instituto de Astrofísica e

Ciências, or IA), three science communicators, two designers, and two active school teachers. In addition to its regular science communication activities (e.g., planetarium shows, telescope observation nights and hands-on activities), PP-CCV produces full-dome shows, exhibitions (many linked to IA's scientific outputs), art shows (see Figure 1), supports national education programmes (e.g., the science clubs school network and the science school network) and promotes research in science communication and education (e.g., *Reis, 2021; Costa et al., 2023*; or compiled at CoAstro website¹).

Astronomy education in the Portuguese compulsory schooling

Since 2009, school attendance in Portugal has been compulsory between the ages of 5 and 18 (1st to 12th grade). Within this framework, education is universal and free of charge, which is a key aspect of



Figure 1: NOOITO: example of a concert held inside PP-CCV's dome. Image Credit: PLANETÁRIO DO PORTO CCV

democratising access to science (e.g., Costa et al., 2022a). For some children and teenagers, it may be the only opportunity to be engaged with astronomy; this is particularly important as awareness is a precondition of interest and enjoyment of science (e.g., Price & Lee, 2013; Oliveira & Carvalho, 2015). Further, Dang & Russo (2015) demonstrate that astronomy interest is shaped at an early age. Thus, it is necessary to expose school children to astronomy content and processes early on within the Portuguese national curriculum, not only for astronomy education but also for the future of national astronomy research.

Costa et al. (2022a) investigated the compulsory education syllabi in Portugal from the 1990s alongside visitors' experiences at PP-CCV. They found that astronomy has gradually disappeared as new curricula have been developed. For example, in the latest Portuguese major curriculum changes, astronomy content is explicit in very few school years and a sparse number of subjects. When astronomy content is included, it is sporadic and superficial, with limited astronomy themes, some of which are considered by research as less relevant. The 7th grade is the only exception in this scenario: students have one theme about the "Solar System & Universe". This becomes more relevant by realising that the most recent curriculum changes are the national benchmarks for

external assessment – the national exams – implying that these essential learnings are the only content covered in Portuguese classrooms. As astronomy education in schools decreases, the number of school visitors to the Planetarium also decreases (Costa et al., 2022a). The authors found that even after it was demonstrated that astronomy functions as a gateway science for education in STEM fields and social

sciences alike (e.g., Salimpour et al., 2020), there was still a decline in astronomy education in Portuguese schools.

Costa et al. (2022a) also pointed out that most teachers who attended training courses at PP-CCV had no prior training nor a particular interest in astronomy, so they do not spontaneously engage with in-service training in this field, and avoid teaching astronomy contents of their syllabus.

Science communication through astronomy education at the PP-CCV

Aware of the context described above, in an ongoing process since 2016, PP-CCV conceived, developed, implemented, and evaluated a new science education strategy. In response to the changing landscape of the Portuguese curriculum, PP-CCV designed a science communication strategy through astronomy education to address the decline in school visits. To do so, PP-CCV established two main pillars: the PP-CCV Educational Programme and the PP-CCV In-service Teachers Training Plan.

In parallel, PP-CCV maintains its daily programming for other types of audiences. Therefore, PP-CCV has planetarium shows, hands-on laboratories, observations with small telescopes (Figure 2), talks, exhibitions, workshops (on topics such as



Figure 2: A public night sky telescope observation at PP-CCV. Image Credit: PLANETÁRIO DO PORTO CCV

robotics and astronomy), and special events, both in-person and online.

However, the focus of this present work is the strategy implemented with schools, their students, and teachers. That strategy allows for all the activities to be done in PP-CCV's facilities or at schools (both in-person or online; see Figure 3).

PP-CCV educational programme

Outlining an educational programme that would make informal education in Astronomy at the PP-CCV more efficient began by analysing all of PP-CCV's resources. Since 2016, these resources have been cross-checked with the curricular programmes, guidelines, and targets for compulsory schooling, from pre-school to secondary school. Based on this analysis, we have continuously outlined didactic sequences based on the most up-to-date scientific knowledge and processes: we address the curricular standards using Contemporary science as a starting point.

PP-CCV has an educational programme with 45 different didactic sequences, covering all years of mandatory schooling from 19 different disciplinary curricular fields. Teachers can also make a disciplinary, multidisciplinary, or interdisciplinary visit².

One complete didactic sequence for visitors at PP-CCV typically consists of two major activities: full dome shows (Figure 4) and hands-on laboratories (Figure 5). The full dome shows have two distinct parts: a recorded part that includes a short film, a feature film and a live presentation, during which visitors are taken on a trip through the Universe, fostering interaction between the planetarian and the audience.

Typically, each session has two distinct parts: a recorded short film and a main movie, followed by a live presentation that encourages interactions between our astronomers and the audience.

The visit follows the rationale proposed by Orion (1993) and, therefore, includes pre- and post-visit tasks with teachers and students.

As part of the pre-visit tasks, a new booking protocol was introduced that involves analysing all bookings in detail to ensure that all activities are age-



Figure 3: The "Astroteca": driving astronomy to schools. Image Credit: PLANETÁRIO DO PORTO CCV



Figure 4: A PP-CCV full-dome show. Image Credit: PLANETÁRIO DO PORTO CCV

appropriate and meet the teachers' objectives for the visit. At this stage, we analyse, with teachers, the details of the visiting groups: size, age, guidance by the teachers, and orientation of the group (science or not, focused on reaching higher education or going towards a profession, and so on). In fact, teachers co-create with the astronomers, and all of

the students work with PP-CCV. This pre-visit work also resulted in creating detailed weekly work schedule maps for the facilitators, including all activities. Post-visit tasks include gathering follow-up information from the visiting teachers with a system we created that produces an attendance certificate and allows teachers to evaluate the work of the PP-CCV: this is



Figure 5: Students during one of PP-CCV's hands-on laboratories. Image Credit: PLANETÁRIO DO PORTO CCV

one of the post-visit tasks. That feedback reshapes PP-CCV activity in a truly co-creative process.

PP-CCV In-service Teachers Training Plan

In-service teacher training is mandatory for career progression. Building on that and upon the in-service training limitation in Portugal, PP-CCV started their training plan in 2016. In it, PP-CCV offers the expected basic knowledge but adds an "attitude towards science" dimension, which guides this action. In PP-CCV's training plan, we still give teachers the necessary knowledge in astronomy but also change how they view science, its nature and how it is built – its epistemological component.

To that process, two key steps were crucial: creating PP-CCV's teacher database and establishing partnerships. Indeed, PP-CCV's In-service Teachers Training Plan is verified by trainers from the Institute for Astrophysics and Space Science (IA), with pedagogic accreditation and endorsement by several institutions. We work with several governmental "School Association Training Centers" and the Regional Government of the Azores and Madeira autonomous regions. We also work with international partners, such as the International Astronomical Union (IAU), the Network for Astronomy School Education (NASE), the European Association for Astronomy

Education (EAAE), the European Southern Observatory (ESO), the European Space Education Resource Office (ESERO), and Scientix.

Regarding our database: as we already said, to receive a personalised attendance certificate after each school visit, teachers were asked to provide some data (name, recruitment group, and contact information), which, if they so desire, can be used to receive regular information about PP-CCV's activity. So far, the database has 3660 entries.

This programme³, available by application only, has had thousands of applications since 2017 from teachers with a diverse type of initial training (e.g., sciences, arts and languages) and ailing from all the Portuguese territories, plus some countries where Portuguese is one of the official languages, such as East Timor or Mozambique. After screening the applicants through a rigorous review process, we accepted about 1,000 applications (Costa *et al.*, 2022b). The accepted applicant pool represented a global population of educators. Those who were not able to join in person were able to participate online.

Data from those courses (discussed below) revealed that teachers value PP-CCV's training: it is clearly linked to their disciplinary field, eminently hands-on, accredited and

recognised for professional progression based on updated scientific results and processes. This type of training allows teachers to move from a professional obligation to a meaningful personal endeavour. It also allows the transformation of in-service training into real paths of professional development: teachers' autonomous learning of astronomy, carrying out astronomy education activities beyond the curricular imperative and stimulating collaborative work among peers.

PP-CCV's Educational Programme assessment

Although we already have data to assess the PP-CCV In-service Teachers Training Plan, these data have not yet been published. Therefore, in this section, we will be restricted to the data from the assessment of the PP-CCV Educational Programme.

We used a questionnaire, participant observations and interviews to assess the effectiveness of PP-CCV's Educational Programme. The questionnaire was based on a survey produced by the Portuguese Agency for Scientific and Technological Culture (available in annexe in Reis, 2021) and adapted to fit PP-CCV's specific activities.

A preliminary version of the questionnaire was analysed and improved upon by an expert in science education and used in a pilot study (for facial and content validation). After the pilot study, we hosted the questionnaire online⁴ and sent it to the teachers who accompanied their students to the PP-CCV.

We received 270 responses, analysed using a content analysis framework for open-ended questions and statistical analysis for closed-ended questions (Costa *et al.*, 2023).

The results (Costa *et al.*, 2023) show that 80.7% of teachers were happy about how they were welcomed, and 85.2% were happy about how they were accompanied throughout the activities. The planetarium shows were most appreciated, but the hands-on laboratories, which complement these shows, were also highlighted. Both activities were considered assets for teachers' classes, with the hands-on laboratories graded with an average of 4.4 and the immersive show with 4.7 (on a 1 to

5 scale). Both activities were also considered well framed in the syllabus, rating 4.2 on average; 97.4% of teachers said they would return to PP-CCV with their students and 72.2% with their families. The most positive aspects of the planetarium shows were the visual component, its framework in the syllabus, the interactivity with the students and the performance of the planetarians. Most visiting teachers (71.4%) thought the shows had no negative aspects. However, it was mentioned that PP-CCV should consider presenting longer shows (8.9%). Teachers often (42.9%) noted that allowing students to conduct experiments by themselves was the most positive aspect of the hands-on laboratories. Teachers also (22.9%) praised the performance of the planetarians. Many visitors (48.4%) stated that the laboratory activity had no negative aspects, but some (12.9%) mentioned that the student groups should be smaller in the future.

Final remarks

The results presented here demonstrate the effectiveness of connecting science education and science communication through outreach structures already established in research units. This allows the reciprocal opening of the school to the surrounding community and, very importantly, the reciprocal opening of science to society. Indeed, that enables the community to better understand an institution, allowing new projects to arise and facilitating improvements to programmes' infrastructure.

To achieve this, outreach institutions must have a deep understanding of the school curricula and design their activities accordingly. This requires working with teachers, co-creating with them (e.g., the CoAstro project¹), and valuing their input.

In the future, we want to engage more teachers to reach more students, especially those far away from the science centres (and research units in general – democratising access to science). We additionally want to produce educational resources with a particular feature: those based on scientific innovations directly linked to the syllabus. In this way, our materials can be repurposed as alternative resources for educators to engage their learners in the practice of science.

Notes

- ¹ COASTRO: @N ASTRONOMY CONDO: <https://condominio.astro.up.pt>
- ² At the Planetário do Porto website, visitors can choose didactic sequences by school year or subject. These sequences include shows and hands-on activities. <http://www.planetario.up.pt/pt/planearescolas>
- ³ The Teachers Training Plan at the Planetário do Porto: http://planetario.up.pt/pt/evento/formacaodocente23_24
- ⁴ The online questionnaire can be found at this link: <https://apps.astro.up.pt/inqueritos/index.php/265879>

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Biographies

Ilídio André Costa has a degree in biology and geology education, a Master's in astronomy education, and a Ph.D. in teaching and dissemination of sciences. He is a middle and high school teacher but was deployed to PP-CCV in recent years. In addition, he is an author of textbooks on Natural Sciences, a teacher trainer, and, more recently, a researcher at IA.

Ricardo Cardoso Reis has a bachelor's degree in astronomy and a Master's in science education and communication. He is involved in strategy for the promotion of scientific culture by producing and presenting planetarium shows, writing press releases about research, presenting telescope observation nights (and days), and guiding hands-on activities.

Elsa Moreira is a driven astronomer with several years of experience in science and astronomy outreach. She is dedicated to remaining current with the latest technologies, methodologies, and trends in astronomy dissemination, bringing forth technical abilities in communication and the desire to provide the public with more knowledge about our Universe.