CUADERNOS.INFO Nº 52
Versión electrónica: ISSN 0719-367x
http://www.cuadernos.info
https://doi.org/10.7764/cdi.52.39405

Received: 01-09-2021 / Aceppted: 02-03-2022

Citizen science through schools: the importance of interpersonal relationships

La ciencia ciudadana a través de la escuela: la importancia de las relaciones interpersonales

Ciência cidadã através da escola: a importância das relações interpessoais

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ABSTRACT | The CoAstro: @n Astronomy Condo citizen science project engages, in a mediated process, teachers, astronomers, and science communicators in research and science communication/science education practices. In CoAstro, scientific research objectives were aligned with science communication/science education objectives to engage public with low astronomy awareness. One of CoAstro´s goals was to understand the effects of the relationships established among the participants, because these are key aspects for engagement. We conducted a case study following the participants during an academic year and collected data through interviews and participant observations. A focus group meeting followed those data collection techniques. The results show the personal benefits of established relationships, institutional effects, changes in the perceived identity roles, and the ability to understand and engage in astronomy research and astronomy communication/education. Understanding social interactions contributes to increase the scope of citizen science projects' and demonstrates its relevance to engaging scientists, science communicators, and school communities, pointing to a path for community empowerment and engagement with science; i.e., a path to unveil a citizen science that moves from mere citizenship to personal comprehensive development: attitudes but also, knowledge.

KEYWORDS: citizen science; public engagement with science and technology; science communication; science education; astronomy.

HOW TO CITE

Costa, I. A., Morais, C., & Monteiro, M. J. (2022). Citizen science through schools: the importance of interpersonal relationships. *Cuadernos.info*, (52), 113-135. https://doi.org/10.7764/cdi.52.39405

RESUMEN | *El proyecto de ciencia ciudadana CoAstro: un Condominio de astronomí@ involucra, en un proceso mediado, a profesores, astrónomos y comunicadores científicos en la investigación y en las prácticas de comunicación y educación científica. En CoAstro, los objetivos de la investigación científica se alinearon con los de la comunicación y la enseñanza de la ciencia para involucrar al público con escaso conocimiento de la astronomía. Uno de los objetivos de CoAstro era comprender los efectos de las relaciones establecidas entre los participantes, ya que son aspectos clave para el compromiso. Se realizó un estudio de caso, siguiendo a los participantes durante un año académico, con datos recogidos mediante entrevistas y observaciones participantes. A estas técnicas les siguió una reunión de grupo focal. Los resultados muestran los beneficios personales de las relaciones establecidas, los efectos institucionales, los cambios en los roles de identidad percibidos y la capacidad de entender y comprometerse con la investigación astronómica y la comunicación/educación astronómica. La comprensión de las interacciones sociales contribuye a aumentar el alcance de los proyectos de ciencia ciudadana y demuestra su relevancia para involucrar a los científicos, los comunicadores de la ciencia y las comunidades escolares, señalando un camino para el empoderamiento de la comunidad y el compromiso con la ciencia; es decir, un camino para desvelar una ciencia ciudadana que pase de la mera ciudadanía al desarrollo personal integral: actitudes, pero también conocimientos.*

PALABRAS CLAVE: *ciencia ciudadana; compromiso público con la ciencia y la tecnología; comunicación científica; educación científica; astronomía.*

RESUMO | O projeto de ciência cidadã CoAstro: um Condomínio de Astronomi@ envolve, num processo mediado, professores, astrônomos, e comunicadores de ciência na investigação e práticas de comunicação científica/educação científica. No CoAstro,os objetivos da pesquisa científica foram alinhados com os objetivos de comunicação científica/educação científica, de forma a envolver o público pouco interessado pela astronomia. Um dos objetivos do CoAstro era compreender os efeitos das relações estabelecidas entre os participantes, pois elas constituem-se como aspetos chave para o envolvimento com a ciência. Foi realizado um estudo de caso seguindo os participantes durante um ano letivo e coletamos dados através de entrevistas e observações dos participantes. Após uma reunião do grupo focal, seguimos essas técnicas de coleta de dados. Os resultados mostram benefícios pessoais das relações estabelecidas, efeitos institucionais, mudanças nos róis de identidade percebidos, e a capacidade de compreender e envolver-se na investigação astronômica e na comunicação/educação em astronomia. A compreensão das interações sociais contribui para aumentar o âmbito dos projetos científicos dos cidadãos e demonstra a sua relevância para o envolvimento de cientistas, comunicadores de ciência e comunidades escolares, apontando um caminho para o empoderamento da comunidade e o seu envolvimento com a ciência,isto é, um caminho para revelar uma ciência cidadã que passa da mera cidadania para o desenvolvimento integral pessoal: atitudes, mas também conhecimento.

PALAVRAS-CHAVE: ciência cidadã; envolvimento público com a ciência e a tecnologia; comunicação científica; educação científica astronomia.

INTRODUCTION

Since most citizen science projects are driven by their scientific goals, citizens' needs and expectations are frequently overlooked and little attention is given to the impact they have on their participants. However, understanding the effects of the relationships established between their participants –scientists, lay public, and other stakeholders– is one of the crucial aspects for public to engage into citizen science projects. Since the number of studies which focus on these relationships is limited (Price & Lee, 2013), to address this problem we designed, implemented, and assessed the citizen science project *CoAstro: @n Astronomy Condo*. In it, we built *the condo* –a shared affinity space (virtual and in person)– where the stakeholders (astronomers, science communicators, and teachers) share their knowledge to the service of the common space.

CoAstro's assessment is focused on its lay public: the primary teachers, who had no initial or continuous training in astronomy, despite having to teach astronomy subjects in their classrooms. We analyzed *CoAstro´s* impact in their astronomy knowledge, attitudes, and beliefs towards science and in how they participated in the scientific processes. However, in this article, we take a different approach: we aim to understand the perceptions of *CoAstro´s* participants (teachers, scientists, and science communicators) regarding their roles and the relationships between them in a citizen science project where scientific research objectives and science communication/science education objectives are equally considered.

The citizen science framework

The first usage of the term citizen science refers to a scientific technique that engages citizens (non-specialized people) in the scientific process, leading to new scientific knowledge (Haklay et al., 2021). However, citizen science is also an open science mechanism, as shown in the recent *UNESCO Recommendation on Open Science* (UNESCO, 2021). Indeed, citizen science is a method for the PEST (public engagement with science and technology) science communication paradigm: involving members of the public directly in the process of research (Haklay et al., 2021; Martin, 2017). Accomplish science communication goals is, indeed, one of the most common purposes of citizen science, pointed out by scientists and citizen science project managers alike (Burgess et al., 2017). The European Citizen Science Association (ECSA) argues that citizen science can have science communication and education outputs, concluding that it provides opportunities for public engagement and for the democratization of science (European Citizen Science Association, 2015).

Gray et al., (2012) also see citizen science as a complement to science education models. This idea came from the dialogue that these projects allow with experts,

supporting access to reliable and updated bibliographic sources. These projects can also be starting points for promoting critical analysis skills. Finally, citizen science can be the cradle of scientifically valid proposals and measurable goals for education (Couvet et al., 2008). Thus, citizen science could help to bridge the gap between research and science education (Gilbert et al., 2011; Senabre et al., 2018).

As demonstrated by Martin (2017), groups with high levels of engagement in science are more interested in volunteering and more likely to participate in research roles than those with lower scores in science engagement. In the specific case of teachers, school cultures in which these collaborate, investigate, experiment, and take informed risks are often correlated with high levels of research engagement (Walker et al., 2018).

According to Hecker and Wicke (2019), the citizen science roles resemble to traditional roles: there are little innovative role changes in citizen science projects. These authors verify that the one reserved for political actors is to support citizen science practices and benefit from these practices results. However, the one reserved for members of society is mainly to observe, contribute, and act as local agents. Scientists and their institutions take on the role of project managers, disseminating and promoting those practices (Hecker & Wicke, 2019).

Despite these conclusions, defining and designing participants' roles is a crucial aspect of citizen science (Hoadley, 2018). Indeed, many citizen science models are based on these roles (Bonney et al., 2009). Therefore, these authors assume instrumental roles for citizen science participants: cocreators of research, data collectors, data analysts.

Participants' roles

Given the centrality of the roles and the relationships established between the participants (Llorente et al., 2019) when designing these projects, we developed *CoAstro* framed in the participatory model of science communication (Lewenstein & Brossard, 2006). In *CoAstro,* the participants' roles did not have the instrumental character (Bonney et al., 2009; Hecker & Wicke, 2019; Hoadley, 2018) often linked to the engagement of volunteers in citizen science; more than framing the nature of the engagement (data collector or data analyst), they refer to each profession's functional content (table 1).

CoAstro was created, as proposed by Jordan et al. (2011), based on the main motivations documented for citizen science projects. The two most valued by teachers –the tangibility of the proposed scientific topics and the personal investment in the scientists' tasks (Rotman et al., 2012; Trumbull et al., 2000)– were the basis for the integration of the mediator role.

Participants	Role
Astronomers	Astronomy scientific research team leaders Teachers´ skills capacitation for research Engagement in astronomy communication/education activities
Science communicators (specialized in astronomy)	Teachers´ skills training for research and astronomy communication/education Engagement in astronomy communication/education activities
Teachers	Engagement in scientific research in astronomy Planning and implementation of dissemination of astronomy activities, for schools' communities
Mediator	Project coordination and evaluation Articulation between all *CoAstro´*s participants Production of task guides Training participants for skills outside the functional content of their profession (but of the functional content of other *CoAstro´*s participants)

Table 1. *CoAstro´*s participants roles

Source: Own elaboration.

This role (table 1) could relieve work pressure on astronomers and, on the other hand, articulate semantic fields between astronomers and teachers. This would make it possible to create specific training moments (Wiggins et al., 2011), or advice and guidance moments for participants, as advocated by Trumbull et al., (2000), improving the communication flow –a common obstacle in citizen science (Price & Lee, 2013). The mediator could also be available to produce the task guides proposed by Wiggins et al. (2011) and to manage potential conflicts (Jordan et al., 2011) resulting from participants´ different goals (scientific, educational, social) and perceptions (Llorente et al., 2019). We knew that the amount of time spent on the coordination effort could be high (Tulloch et al., 2013); therefore, this could not be a task attributed to astronomers, teachers, or science communicators. Given its characteristics, motivating participants for *CoAstro* would only be the beginning of the process, and participant retention throughout the project would be just as essential. Due to the participants' inexperience, our focus was on the relationships between them (Curtis, 2015; Rotman et al., 2012), adding personal (bilateral and group) interactions to the remote interactions.

Teachers had one of the central roles in *CoAstro*: engage in astronomy research and present research results to their school communities. This school effect and teacher effect has been the subject of numerous studies since the 1960s, which

are summarized, for example, in the works of Gilbert et al. (2011) and Heafner (2019): teachers are a significant factor associated with student achievement. On the other hand, the advantages of associating science communication and science education are well known (Panizzon et al., 2018; Walker et al., 2018), as education quality is a determining factor in attitudes towards science (Osborne et al., 2003).

The teachers' engagement in citizen science projects is even more relevant when we realize that academic research has a relatively small impact on teachers' pedagogical decisions (Walker et al., 2018). Additionally, as stated by the Center on the Developing Child at Harvard University (2016), these teachers work with children's in age ranges whose brain capacity to change, in response to experiment, is at the highest. We also know that astronomy interest is shaped early in life (Dang & Russo, 2015).

CoAstro´s astronomers assumed two main roles: leading the scientific research team where teachers were integrated and support their science communication/ science education initiatives. For the latter, the science communicator assumed a crucial role, thus astronomers had to be able to speak Portuguese and be available to go to schools.

Horizontal relationships were not imposed externally; they emerged naturally from each participant's role, with astronomers being the research experts, science communicators the experts in communicating astronomy, and teachers knowing best the context of their school communities. Thus, the success of all these roles depended on the existence of each one of those participants.

CoAstro citizen science project

CoAstro´s first edition started in 2019 and it is still ongoing (although we already started the second edition). It had the participation of (table 1) astronomers from the Institute of Astrophysics and Space Sciences (IA), in Portugal, primary school teachers, science communicators, and one mediator (these last two groups belonging to the Porto Planetarium –Ciência Viva Center– PP-CCV). *CoAstro´s* main goal is to disseminate scientific knowledge and processes to lay public, which normally would not spontaneously engage with astronomy. As a citizen project, *CoAstro* has scientific outputs (new scientific knowledge), but also science education and science communication outputs. Therefore, *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 (figure 1).

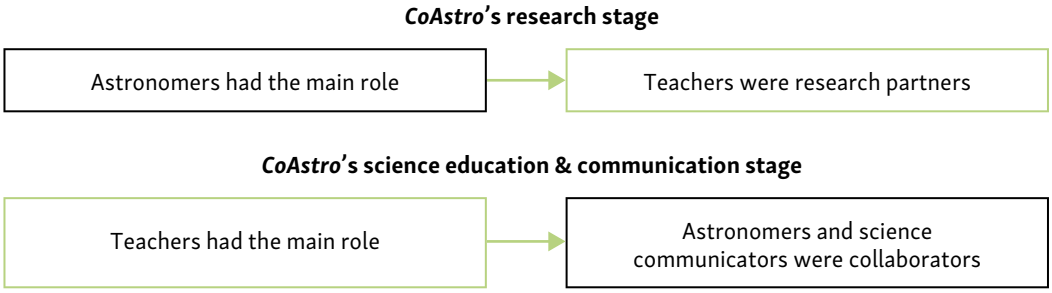

Figure 1. *CoAstro*´s stages

Source: Own elaboration.

CoAstro´s research stage

Within *CoAstro*, two specific research projects were developed to address astronomers' scientific needs: *Stars* and *Planets* (figure 2). This stage went from January to July of 2019, and had both online and face-to-face interactions.

In *Stars Project*, teachers started by analyzing standard stellar spectra (light from the stars), obtaining several stellar parameters. From this observational data, teachers calculated the stars luminosity and classified them. After this work, astronomers checked if these luminosities could be validated, with new parameters from the GAIA Data Release 2 catalogue (the new quantities were measured by the European Space Agency's -ESA- GAIA Mission).

In *Planets Project*, teachers learned to work with the Python programming language and used it, in a collaborative work, to produce a video of a Mercury transit (Mercury passing in front of the Sun). Teachers were now able to signal to Oxford University astronomers, through the Planet Hunters platform, the existence of potential exoplanets (planets outside the Solar System) in data from the Transiting Exoplanet Survey Satellite (TESS/NASA) space mission.

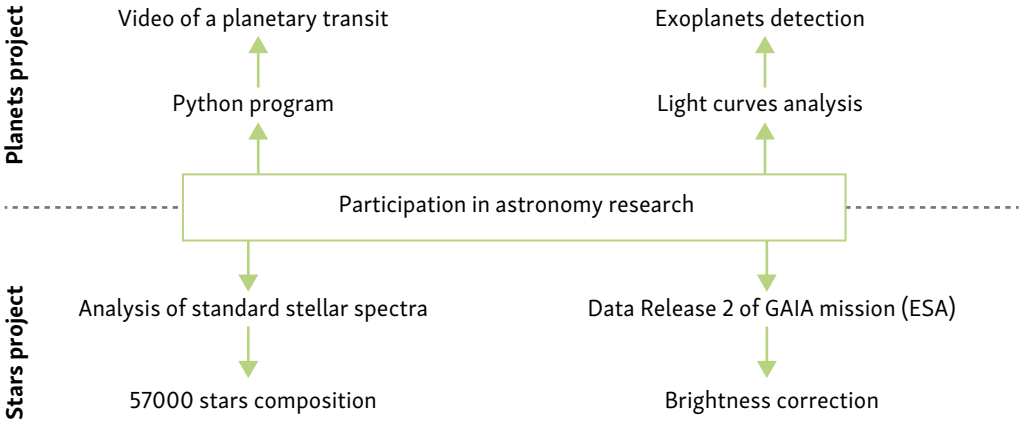

Figure 2. *CoAstro* research tasks

Source: Own elaboration.

This *CoAstro´s* research stage culminated with the presentation, to the school community, of the research results. The research stage had two main scientific outputs, with teachers contributing to determine the composition of 57,000 stars and characterize their brightness, and validating the first discovery and characterization of a planet identified by Planet Hunters TESS, with results published in the scientific journal *Monthly Notices of the Royal Astronomical Society*.

CoAstro´s science education & communication stage

This stage started in February, 2019, and still ongoing, included astronomy communication/astronomy education activities conducted in schools. In it, the whole school community interacts face-to-face with astronomers and science communicators.

It began with 25 hours of in-person teacher training, based on the European Space Educational European Space Education Resource Office (ESERO) kit (Machado et al., 2016), carried out by *CoAstro´s* mediator and one of *CoAstro's* science communicators. The kit provides teachers a diversity of tools, which can be used to teach several school subjects, through astronomy. This teacher training, in tandem with the research stage, allowed teachers to build astronomy communication/astronomy education initiatives. Starting from the specific context of their schools (its potentials and limitations) and drawing from the experience acquired in the first *CoAstro* stage, teachers freely devised the best way to engage their school communities, with support from the astronomers and the science communicators in the implementation of the activities, while the mediator articulated the process.

METHOD

In this section, we will describe our participants and the research methodology which allowed us to understand the perceptions of *CoAstro´s* participants (teachers, scientists, and science communicators) about their roles and the relationships established.

Sample

For this work our sample (table 2) had nine teachers, five astronomers, and four science communicators (specialized in astronomy). No compensation was offered to integrate *CoAstro* research.

Our sample is a convenience sample (non-probabilistic), because its elements were volunteers and were selected according to the following criteria: for teachers, being primary teachers (as already justified in the participants' roles section), fully aware of the characteristics of the project, and agreeing to participate in all its stages. Astronomers and communicators, besides meeting the previous criteria, needed to speak Portuguese and be available to travel to schools to be able to conduct activities for the dissemination of astronomy.

Participants	Gender	Nationality	Mean age (or age)	Average or years of professional experience
Astronomers	3 males 2 females	3 Portuguese 1 French 1 Brazilian	35	11
Science communicators	3 males 1 female	4 Portuguese	37	14
Teachers	8 females 1 male	9 Portuguese	45	22

Table 2. *CoAstro´*s sample

Source: Own elaboration

All teachers stated that they had never taken any astronomy courses nor participated in any initiative within that science scope.

Though their participation was not anonymous, teachers' personal data were confidential. The project had on one intranet server to store and anonymize data, with access to data in physical supports restricted to researchers. An informed consent with these procedures was collected via a signed printed form.

Research methodology

Given our sample size and the nature of *CoAstro* design work, we chose to implement a longitudinal study (between January and July of 2019) that allowed us to follow a small group of participants. Such characteristics are consistent with a qualitative case study. According to Creswell (2013), in case study research the researcher explores, in a longitudinal, in-depth way, one reality with well-defined boundaries through multiple data sources.

The data collection techniques are determined according to the research classification. Thus, and specifically for the purpose of this article, we used an interview survey (carried out in July, 2019) and participant observations (conducted by the mediator during all *CoAstro* activities between January and July, 2019), with interview scripts and field notes as data collection instruments.

The interview goals led to the production of the interview scripts that, with slight adaptations, included the same questions for the three groups (teachers, astronomers, and science communicators) and allowed the definition of *a priori* analysis categories and subcategories (table 3).

We chose e-mail to deliver and receive the answers of the interview script (Gay et al., 2012). Email was also used to clarify any doubts participants had from the preliminary analysis. To overcome this type of data collection limitations, the interview was followed by a focus group meeting, streamlined by the mediator.

Category	Subcategory	Description
A. Relationships	A1. With the other *CoAstro´s* participants	Description of the interpersonal relationships among participants and how it affects: i) the image of each professional profile, ii) the desire to remain in the project
	A2. With lay public	How they see their participation in *CoAstro´s* communicational/educational activities and effects on the lay public
B. Reflections	B1. Institutional	Reflections on the effects of *CoAstro* for the institutions involved (IA, PP-CCV, and schools) and for the participants' profession
	B2. Personal	Reflections on *CoAstro´s* personal effects and its significance

Table 3. Interview categorization structure

Source: Own elaboration.

In it, all the interview participants presented their interview answers to each other, in person. Such was the motto for the subsequent reflection.

RESULTS

In this section, we will triangulate the interview results with observation and focus group data. Results emerge from the combination of those techniques, enlarging the data collection and allowing the observations risks of subjectivity control.

Excerpts from the interviews will be referenced in each analysis category and subcategories (table 3). Respondents are identified, in coded form, by the initials T (teacher), A (astronomer), S (science communicator), and a number.

Relationships

Here we analyze *CoAstro* participants' relationships with each other and with the lay public.

With the other CoAstro´s participants

Data analysis reveals changes in teachers' perceptions about astronomers' role and their work.

> Uses observations data, using a computer, especially with an internet connection [...]. The contact with the astronomers made me admire even more those who study and produce knowledge in this area (T1).

CoAstro seems to have contributed to teachers understanding other areas of the astronomer's work (besides research), such as their participation in science communication.

From interviews, it is also clear that the teachers recognize the role of astronomers and science communicators in conducting research and supporting astronomy communication/astronomy education activities. One aspect highlighted by the teachers is related to the fluidity that the participation of astronomers and science communicators allowed, namely in the transition of innovative knowledge (produced in Portugal) to school communities. From the relational point of view, the informality and the horizontal relationships were positively outlined by teachers.

> The participation of the scientists was important [...]. Most parents loved and appreciated, on the one hand, the fact that the school participates in a partnership [...] and, on the other hand, the proximity of an updated and immediate knowledge [...], recent and made by Portuguese, in Portugal (T5).

Astronomers also changed their view about teachers' roles, emphasizing their work's nature and the motivation for tasks that go beyond their work obligations, and contribute to their professional and personal development. However, with *CoAstro*, there were no significant changes in science communicators perception about teachers and researchers. This seems to be related to the fact that their everyday work includes the relationship with both professional classes.

Observations data triangulation also reveals that, without the mediator's intervention, the contacts among the teachers and between teachers with both astronomers and science communicators was minimal or non-existent. To overcome this difficulty of reconciling agendas for face-to-face meetings, mostly due to lack of time because of job constrains, the *CoAstro* mediator promoted a component of remote bilateral relationship, which was valued by the participants.

The carried-out analysis led to the identification of two structuring factors, which contributed for teachers to remain in *CoAstro* until the end: a self-centered one (the desire to overcome themselves) and a relationship one (the commitment to the group) – they did not want to defraud the expectations and confidence of other *CoAstro's* participants. On the astronomers' side, this permanence factor was also identified, highlighting teachers' engagement and their dedication to the research investigation.

> The external incitement of wanting to take this to the end without letting anyone down [...]. A condo, where everyone seeks the common good, where we work towards a collective goal(s), and where the themes are captivating, it is an exemplary condo that fulfils its functions, and that was precisely what I felt at *CoAstro*, and that led me to get to this point (T1).

> The engagement of teachers and their dedication to the research component was also an important example to maintain my engagement in the project and my contribution to the school visit component (A1).

However, in the science communicators case, it was not the relationships that justified their stay in *CoAstro*. They pointed out the nature of *CoAstro*, its intrinsic characteristics: the astronomy procedural knowledge that it allows, the fact that its effects can last over time, the very idea behind it, and its methodology.

CoAstro appears to have changed the astronomers' view about science communicators work, with a better understanding of the wealth of resources and strategies they have, to work with non-specialized and diverse audiences (in terms of age, interest in tasks, and base knowledge). They also seem to understand the role of the science communicators (not specifically the *CoAstro* mediator) in the transformation of knowledge into social representation: they are not just translators, but also creators – they are the ones which seek the meaning that the public attributes to what is being communicated. Astronomers also value the roles of science communicators in the way they supported, in *CoAstro*, astronomers' communication practices.

> I found it interesting that being a science communicator includes doing research (sociological, pedagogical). I realized that the job of the science communicator is not only translation but also requires knowledge creation (A3).

CoAstro also valued the role of science communicators in their job. Indeed, these professionals perceive their role in the project as essential, given their work with the public. This seems to result from the gain astronomy research has, for non-specialized audiences, due to the work done by these science communicators.

About astronomers, science communicators assign them the main role, given the coordination they carried out in the scientific research projects. Without them, *CoAstro* would not have the same potential for motivation and procedural understanding of astronomy.

> The presence of researchers helped teachers to understand what is really being done in a research center (S2).

Data shows that teachers, astronomers, and science communicators reserve the decisive role for the mediator throughout *CoAstro*, due to his sensitivity to the problems and needs existing in the research, communication, and teaching fields. Someone who knows the daily life of research/communication and is aware of a teacher's everyday life. That has also become evident in his role as a language translator to find a joint communication base between astronomers, science communicators, and teachers. His contribution was also highlighted in tracking the project's schedule. Another aspect about the role of the mediator that stood out was that he allowed teachers to engage in many other fields beyond the astronomy research they carried out: the news that he sent, the resources and knowledge that he shared, which were useful to the teachers' daily lives.

> The mediator is essential to create a positive, constructive, efficient, and pleasant work environment for all participants. It also has the thankless task of ensuring that researchers do their part of the work and that teachers can maintain an adequate level of dedication to the project; even when their professional activity does not leave them time to do it (A1).

The mediator's role as a translator of language and skills between astronomers, science communicators, and teachers is reinforced by data triangulation. The task guides produced by him, based on astronomers' documents, were highly valued by teachers.

The data reveal that science communicators recognize that primary teachers are a group with very low astronomy training. Therefore, this requires a more significant number of conceptual acquisitions to participate in a project like *CoAstro*. However, they recognize clear advantages of engaging these teachers because they have greater motivation to learn, willingness to invest time in astronomy-related activities, and an early influence on students' awareness of science.

With lay public

We can firstly identify, besides from the impacts on educational practices (which we will not address in this article), one of the consequences of teachers' relationship with the lay public: the relevance of astronomy in the students' daily lives.

> This idea spread to the rest of the school community, as students talked, during breaks, about what they learned [...]. In parallel to all this work developed in the classroom, I managed to "infect", first, the 4th grade class [...] and second, the whole school from pre-school to 4th-grade (T3).

This greater awareness and interest in astronomy was accompanied by a greater understanding of this science. Thus, in addition to stating that the relationships established between teachers and the lay public opened the school to families, it can also be said that families opened themselves to the school.

> When I asked the children to observe the night sky, I realized that parents, children, and teachers were excited to contemplate the sky and that we were all commenting on what we saw on WhatsApp. I had reports like "Here at home, we just have to thank the children for sharing knowledge..." [...], "yesterday we almost all slept outside!" (T1).

In this regard, it is worth mentioning *CoAstro* participants' deep conviction that teacher/astronomer/science communicators relationships with the lay public were the engine to reach audiences that would hardly ever be engaged with astronomy. That is due to the complete indifference that this science

generated in some students' relatives, often conditioned by wrong ideas, such as the confusion between astronomy and astrology. Thus, the likelihood of these people participating in an astronomy initiative, even if it is free, outside *CoAstro*'s context, would be very slim.

> [It] facilitates science communication in social contexts that might otherwise be outside the PP-CCV initiatives [...]. I sincerely think that *CoAstro* managed to reach socioeconomic environments that would otherwise not have access to scientific communication (A3).

> Maybe these students would never have access to this type of activities [portable planetarium and telescopes observations] otherwise (S3).

What the data either from the interview or from observation also demonstrated is that the network of relationships established through *CoAstro* has effects that are not limited to the moments of relationship between its participants (direct or indirect) (figure 3). Thus, *CoAstro* not only allowed positive views on astronomy (and on how it is built) but also established the foundations for these effects to linger. That has also been evident in activities motivated by *CoAstro´s* relationships, which are still being carried out at PP-CCV.

Data reveal that *CoAstro*'s relationship with the lay public was different from all previously experienced by the astronomers. This came either from the publics' age or from the previously established relationship with teachers.

> Students are clearly different from what I had experienced before [...]. In that sense, it was essential and pleasant to have this direct contact with students in this age group, as it forced me to adjust the way of communicating and led me to learn a little better what knowledge they have, the questions that arise to what they learn at school and beyond, and how we can help to consolidate in them the fundamental principles of the scientific process (A1).

The relationship established between astronomers and teachers during *CoAstro´s* research stage enhanced the astronomy communication activities that astronomers conducted with the lay public. That contributes to reinforce the idea that scientific communication/scientific education carried out after the teachers' engagement in astronomy research may have a more lasting and systemic character.

Reflections

In this category, we analyze the participants' reflections about *CoAstro*'s institutional (IA, PP-CCV, and schools) and personal effects, which give us indicators about the significance of the experience.

Institutional

From an institutional perspective, teachers identify *CoAstro's* influence in two areas: in their classes and in their fellow teachers. Thus, changes in classroom dynamics are evident, both in terms of resources and in methodological terms. Such positioning is reinforced by the observations made.

In the interviews we saw the *CoAstro's* effects also in other teachers (from the same school, or even from other schools) with whom *CoAstro´s* teachers related. *CoAstro* teachers' engagement seems to have opened some avenues of collaborative work that, until then, were not seen/explored.

> It was essential for me to be able to share [...] with my schoolmates [...]: the classes design, the preparation of the activities sequence, the deconstruction of concepts, the verification of the appropriateness of the interventions were always done with them (T8).

For astronomers, *CoAstro* gave visibility to IA and its science, with a range more significant than the limits of a classroom. On the other hand, the project contributed to promoting a goal enshrined in the institute's matrix: science communication. This last aspect is also pointed out by the science communicators, who add another one: *CoAstro* allowed IA research to find another way of communicating, thus contributing to scientific literacy.

> It is an interesting opportunity to create new partnerships with a new audience that can help in a very efficient way to reinforce the visibility of science that is done in IA (A1).

> We won [...] in the long term because it is fundamental for society to understand the importance of science in its daily life and the advantages of public investment in research and development activities (S1).

On the other hand, one of the astronomers explains that the advantages are bidirectional: to IA, for working with teachers, and to the teachers, for working with IA.

> By making teachers partners in what we do, a relationship is built where either side is free to ask and request the collaboration of the other in their regular professional activities (A1).

CoAstro´s institutional contributions also resulted in scientific outputs: i) the determination of the composition of 57,000 stars and the characterization of their brightness and ii) the validation and consequent publication, in the *Monthly Notices of the Royal Astronomical Society*, of the first discovery and characterization of a planet identified by Planet Hunters TESS.

For the PP-CCV, astronomers and science communicators point to the same *CoAstro*'s advantages: promoting PP-CCV image, attracting new audiences, and fulfilling its statutory mission on science communication.

Personal

For teachers, *CoAstro*'s personal impacts are also significant. In the strictly individual domain, astronomy has become an important aspect of their lives.

> I started to have a special admiration for Planets [subject in which s/he did research] and to contemplate more the night sky, to look more at the stars (try to see constellations, which I always had difficulty to identify), and to observe more the Moon phases (T4).

However, astronomy also became present in family relationships and in other interpersonal relationships (extra-professional).

> At home with my son, I find myself talking about planets, constellations, moons, tides, in short, a whole range of themes that in the past I did not value. *CoAstro* brought interest and motivation [...] to my family members [...]: there was a flow of questions and interest that I had not seen for a long time (T6).

Data shows that *CoAstro* contributed to an increase in astronomy interest, which seems to be because astronomy is now more intelligible to them. Observation data allow us to state that the project motivated most teachers to learn astronomy autonomously (and therefore, it conducted to more effective learning practices). Most teachers recognized that they had misconceptions about astronomy.

Astronomers believe that their participation in *CoAstro* allowed the development of new communication skills and new ways of structuring communication practices. In addition, science communicators recognized changes in terms of the adequacy of their practices to the public. Two disseminators also identify changes arising from *CoAstro* regarding their understanding of the main purposes of the communication activities. On the other hand, *CoAstro* contributed, for astronomers, to reinforce their perception about the importance of scientific communication: they realized the complete significance and relevance of the dissemination activities.

> It allowed me to improve my interaction with the public, realizing where I have to improve to make the message clearer and more accessible [...]. The need to adapt the language and the level used for the transmission of the message, mainly for a younger audience and, also, for an interested and educated audience, but lay in astronomy (S4).

> I realized, during school visits, that many children want to know the "why" of things, and not necessarily the "how" [...]. In the future, I will try to align my outreach activities with the stimulus of this curiosity (A3).

The astronomer cited above introduced another personal contribution of *CoAstro*: revealing the current school context. This fact contributes to rethinking of how to structure the communication practices and the contributions that astronomers make to PP-CCV's work. Astronomers thus seem to want to change their practices, based on science communication deficit models, to other models in which context is effectively relevant. They seem inclined, after *CoAstro*, to realize that scientific content must be combined with the scientific process: projects *for* the public become projects *with* the public.

One of the astronomers also focused on the small appreciation the engagement in science communication activities has in her/his career.

DISCUSSION

In addition to the scientific research package, the citizen science project *CoAstro* was also an opportunity to build relationships which support astronomy communication/astronomy education practices, engaging teachers, astronomers, and science communicators in a mediated process.

It was unanimous, among *CoAstro*'s participants, that the project would not have the same results if any of the roles played by teachers, astronomers, and science communicators were suppressed. Thus, all these professionals felt relevant to the project.

The science communicators considered that the project valued their work. These professionals recognized the clear advantages of *CoAstro*, including the role of primary teachers, due to their greater willingness to invest in activities related to astronomy and the early influence they have on students' awareness of science, as advocated by the Center on the Developing Child at Harvard University (2016) and Dang and Russo (2015).

Also, unanimous among *CoAstro*'s participants was the importance of the mediator role in the project. That became especially evident in deadlines fulfilment, in the production of work synthesis documents, and in the production of the task guides suggested by Wiggins et al., (2011) which, at the same time, detailed and simplified what had been produced by astronomers. On the one hand, the mediator served as a facilitator for teachers' access to astronomy information. Thus, results seem to confirm the importance of the mediator's role in two key factors for the citizen science projects' success (Rotman et al., 2012; Trumbull et al., 2000): i) the tangibility of the scientific topics proposed and ii) the scientists' personal investment in the tasks. In the latter, the mediator was decisive in easing the work pressure on astronomers, coordinating the communication with the participants (Tulloch et al., 2013) and

managing the process (Jordan et al., 2011) according to the different participants' objectives (scientific, educational, social) and perceptions (Llorente et al., 2019). On the other hand, the mediator made it possible to create the training moments suggested by Wiggins et al. (2011) and those of the participants' counselling and guidance, as proposed by Trumbull et al. (2000). Thus, the communication flow was improved – a common citizen science obstacle (Price & Lee, 2013).

The relationships between IA's and the PP-CCV's with the extended community made possible by *CoAstro* was noticed by all participants. However, as already stated by Llorente et al. (2019), there is the perception that there is a lack of appreciation of scientits engagement in science communication for an astronomers' career progression.

The relationships established were one of the reasons teachers and astronomers pointed out to remain in *CoAstro* until its end, which is in line with what is advocated by several authors (Curtis, 2015; Rotman et al., 2012). Thus, the collaborative community created in *CoAstro* seems to have led teachers to consider the work as their own, whose structure could be discussed, and not merely imposed by others. This feeling of control was reinforced by the established relationships, which attributed them a role beyond mere data collection and analysis, a fact which has been pointed out as an aspect to be implemented in citizen science.

CoAstro reinforced the perception about the importance and purposes of science communication and promoted, in both astronomers and science communicators, new communication skills and new ways of structuring communication practices – away from the deficit model (Lewenstein & Brossard, 2006).

For astronomers, participation in *CoAstro* changed roles' identity: the way they view the professional class of teachers, as already suggested by Llorente et al. (2019), and science communicators, although the latter did not point out this *CoAstro* effect. However, for all participants, the roles' identity, self-perceived and perceived by others, went far beyond the instrumental content reserved for this roles (Bonney et al., (2009); Hoadley, 2018). In fact, in *CoAstro*, these roles do not shape science communicators models but, instead, manage to overcome the limitation pointed out by Hecker and Wicke (2019). Indeed, *CoAstro´s* restructured the traditional roles, common in conventional sciences approaches and even in citizen science.

CoAstro's results seem to be aligned with the results of other studies (Couvet et al., 2008; Gray et al., 2012), who argue that citizen science can establish relationships between schools, was well as reliable and current information sources. This is even more relevant when we know thanks to Osborne et al (2003) that this same

quality is a crucial factor in students' attitudes towards science, which is directly related to the pursuit of scientific careers.

On the other hand, *CoAstro*'s science communication/science education results seem to have been effectively enhanced by the teachers' roles, confirming on the one hand the school effect and teacher effect (Gilbert et al., 2011; Heafner, 2019) in school communities and, on the other, the advantages of associating science communication with science education (Panizzon et al., 2018; Walker et al., 2018).

Therefore, *CoAstro*'s established relationships led to bilateral opening between the school and families, but also between astronomy research/communication/education and the public, effectively narrowing the gap between research and the public (Gilbert et al., 2011; Senabre et al., 2018), and placing verified scientific results based on teachers' pedagogical decisions (Walker et al., 2018). The extent of the latter allows us to state that its effects tend to last longer (compared to other astronomy communication initiatives), in line with Price and Lee (2013) results, reaching audiences that would hardly ever be engaged with astronomy.

CONCLUSION

The analysis of the relationships between teachers, astronomers, and science communicators allows us to identify the personal benefits of those established relationships, as well as their institutional effects. On the other hand, we see a positive change in the identity of these participants' self and hetero-perceived roles. Still common to all of them is the idea that these horizontal collaborative roles and relationships were the engine for *CoAstro*'s ability to present astronomy to the public, with more lasting effects in audiences that would hardly be spontaneously engaged in this science. Therefore, *CoAstro* shows a path to unveil science, through science education.

For teachers and astronomers, the established relationships kept them in the project until its end, and among the participants, the mediator role was recognized as pivotal in *CoAstro*.

This demonstrates the greater relevance which citizen science projects can have if science communication/science education goals, which consider the importance of the roles and relationships established between the participants, are added to the regular scientific goals. In fact, *CoAstro´s* participants continued their interactions in an initiative intentionally dubbed The *NeverEnding Story*. In this action, astronomy communication/astronomy education takes a main role.

As a major obstacle to *CoAstro´s* citizen science design, all the participants pointed out the time needed to engage in a voluntary-based project. Astronomers and science communicators highlighted another limitation for this engagement: the scant appreciation, in terms of researchers' careers, of their involvement in science communication activities.

Due to the qualitative nature of this study, we do not intend to generalize its results, but to contribute to other contexts and cases in which they may apply. In the future, we would like to analyze which changes would take place in participants' roles, relationships, and in the educational outcomes in a citizen science project in which the non-specialized citizens would establish the scientific question (and/or the structuring of the collection method) and analize and communicate results.

FUNDING

This work was supported by Fundação para a Ciência e Tecnologia – FCT, Portugal [projects UIDB/00081/2020, UIDB/04434/2020 & UIDP/04434/2020].

CoAstro is an ongoing project started in 2018. Principal researcher: Ilídio André Costa.

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