frontiers | Frontiers in Environmental Science

TYPE Community Case Study
PUBLISHED 22 November 2023
DOI 10.3389/fenvs.2023.1270413

OPEN ACCESS

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RECEIVED 31 July 2023
ACCEPTED 25 October 2023
PUBLISHED 22 November 2023

CITATION
Thiel M, Baeza Álvarez J, Diaz M, de Veer D, Dittmann S, Guevara-Torrejón V, Ahumada GH, Honorato-Zimmer D, Kiessling T, Leyton Muñoz A, López-Xalín N, Nuñez P, Sepúlveda JM and Vásquez N (2023), Communication strategies in an international school citizen science program investigating marine litter. *Front. Environ. Sci.* 11:1270413. doi: 10.3389/fenvs.2023.1270413

Communication strategies in an international school citizen science program investigating marine litter

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Communication is an essential element of science, and while it is important in all scientific endeavors, it gains substantial strategic relevance in citizen science projects. For a school citizen science program to be successful, an adequate communication strategy needs to achieve a balance between learning objectives and the generation of scientific knowledge. In this community case study, we report on the communication strategies of an international network, namely, the citizen science program *Científicos de la Basura* (*Litter Scientists*), which collaborates with schoolteachers and schoolchildren to investigate anthropogenic litter on marine beaches and in rivers. The program has been active in Chile since 2007, and as of 2018, it had expanded to the 11 countries from the central and southern East Pacific. More than 40 teachers and collaborators from these countries work in this network making an effort to connect the research activities with the learning objectives of the school curriculum. The communication between the coordination team and the teachers includes three main elements (1 - design and planning; 2 - training and research; 3 - evaluation and sharing), with the following activities: (1a) regular internal communication within the coordination team to design, motivate and supervise adequate research projects, (1b) communication with teachers to design appropriate learning materials (co-creation) and get their feedback on the planned research activities, (2a) sharing the final research plan and transfer methodological skills through regular training of the teachers, (2b) responding to methodological questions by the teachers about the sampling, and coordinate data collection and validation, (3a) guiding teachers and schoolchildren in the evaluation and interpretation of their research results, and (3b) encouraging teachers and schoolchildren to communicate their scientific findings to the wider community. Intense internal communication and regular exchange with teachers guarantees successful learning and rigorous scientific information. The main challenges for the program are team capacity, socio-economic stability, internet access, and teachers' workloads. Recommendations to

achieve successful communication and good science are efficient team communication skills, customized contacts, collaborative work, guidance of field work, feedback from participants, and promoting the sense of community.

KEYWORDS

volunteer participation, schoolchildren, school teachers, learning objectives, education goals, customized communication, research activities, plastic pollution

Introduction

Engaging members of the public in scientific research can have important learning benefits for the participating "citizen scientists" in addition to producing powerful scientific information (Bonney et al., 2009) (note: here we use the term "citizen scientist" to refer to people partaking in research processes, usually without a formal scientific education, even though this term is debated, see, e.g., Eitzel et al., 2017; Heigl et al., 2019). Because citizen science projects typically involve diverse participants from different backgrounds, good communication is especially important (Anderson et al., 2020). Communication for citizen science projects/programs often goes beyond conventional science communication that simply aims to inform the public about research findings in writing or in participatory discussions and presentations (Wagenknecht et al., 2021). Communication in citizen science serves to (i) develop research questions, (ii) design and test methodological approaches, (iii) collect data and samples, (iv) gather and validate the data, (v) analyze data and interpret the results, and ultimately (vi) share the new scientific findings. In particular the internal communication takes different angles (goals) and perspectives (project participants) in citizen science as its desired outcome is project-specific (Rüfenacht et al., 2021; Hecker and Taddicken, 2022).

Many authors emphasize the importance of effective communication with citizen scientists and also with the general public (e.g., Bonney et al., 2009; de Vries et al., 2019; Roche et al., 2020; Dittmann et al., 2023). These communications are essential and usually happen between a team of program professionals coordinating the research projects and the citizen scientists as participants in the investigation. The internal communications among the members of the program teams, usually a team of scientists and citizen science coordinators, are also critical for the success of citizen science projects, yet they are often overlooked when describing the interaction space of these projects. Scientists and project coordinators should reflect regularly about their roles and goals in order to achieve successful citizen science projects (Hecker and Taddicken, 2022).

The dialogue between scientists and participants is especially important in school citizen science projects, because teachers are interested in effective learning outcomes for their schoolchildren whereas scientists place emphasis on data/samples for their scientific research (Zoellick et al., 2012; Atias et al., 2023a). The challenge for school citizen science programs is thus to achieve synergies between the educational goals and the advancement of scientific knowledge (Roche et al., 2020), which requires extensive communication and time (Benichou et al., 2023). In this contribution we share our experiences regarding internal and external communication strategies of the school citizen science program *Científicos de la Basura* (*Litter Scientists*). Members of this program have been investigating marine litter pollution in Chile and Latin America since 2008 (Bravo et al., 2009), making efforts to achieve a sustainable balance between educational and scientific outcomes.

Científicos de la Basura network

The citizen science program *Científicos de la Basura* (*Litter Scientists*) develops annual research projects where scientists collaborate with schoolteachers and schoolchildren (ages 10–18) in the study of anthropogenic litter. The program pursues four main goals: (i) contribute to the scientific education of schoolchildren, (ii) foster environmental awareness among the schoolchildren and local communities, (iii) generate relevant information about anthropogenic litter, and (iv) support decision-makers with useful data (all materials including learning and research guides, outreach reports, and scientific publications are available on the project website: www.cientificosdelabasura.cl).

From 2008 to the present, the program conducted national research projects about microplastics and macrolitter on sandy beaches (Hidalgo-Ruz and Thiel, 2013; Hidalgo-Ruz et al., 2018), litter in the rivers of Chile (Rech et al., 2015; Honorato-Zimmer et al., 2021), and it also surveyed the knowledge, perception and attitude of coastal inhabitants about marine litter (Eastman et al., 2013). In 2016, the program did a first binational project comparing macrolitter on beaches from Chile and Germany (Honorato-Zimmer et al., 2019) and in the following years also contributed to the establishment of the *Plastic Pirates* program in Germany (Kiessling et al., 2019; Dittmann et al., 2023). Both programs work independently, but given the similarity in research protocols they occasionally collaborate, e.g., in exploring how participation in a citizen science project influenced knowledge and attitude of the schoolchildren (Kruse et al., 2020; Wichmann et al., 2022). In 2018, the *Científicos de la Basura* program created the Latin-American Network, integrating the 11 countries between Mexico and Chile that share the Pacific coast.

The program team consists of scientists with extensive expertise in marine litter research and of citizen science coordinators who have worked with teachers and scientific outreach activities for many years (Figure 1). However, these roles are not always strictly separated, as scientists are also involved in coordination, and the coordinators also curate data and contribute to the analysis and interpretation of the results. The coordinators fulfil similar roles as the citizen science enablers in the model suggested by Salmon et al. (2021). In addition, a teacher who has been teaching at a local school for >15 years, and who has participated with his schoolchildren since 2008 was fully integrated in the program team starting in 2018 (J.M. Sepulveda, co-author of this publication).

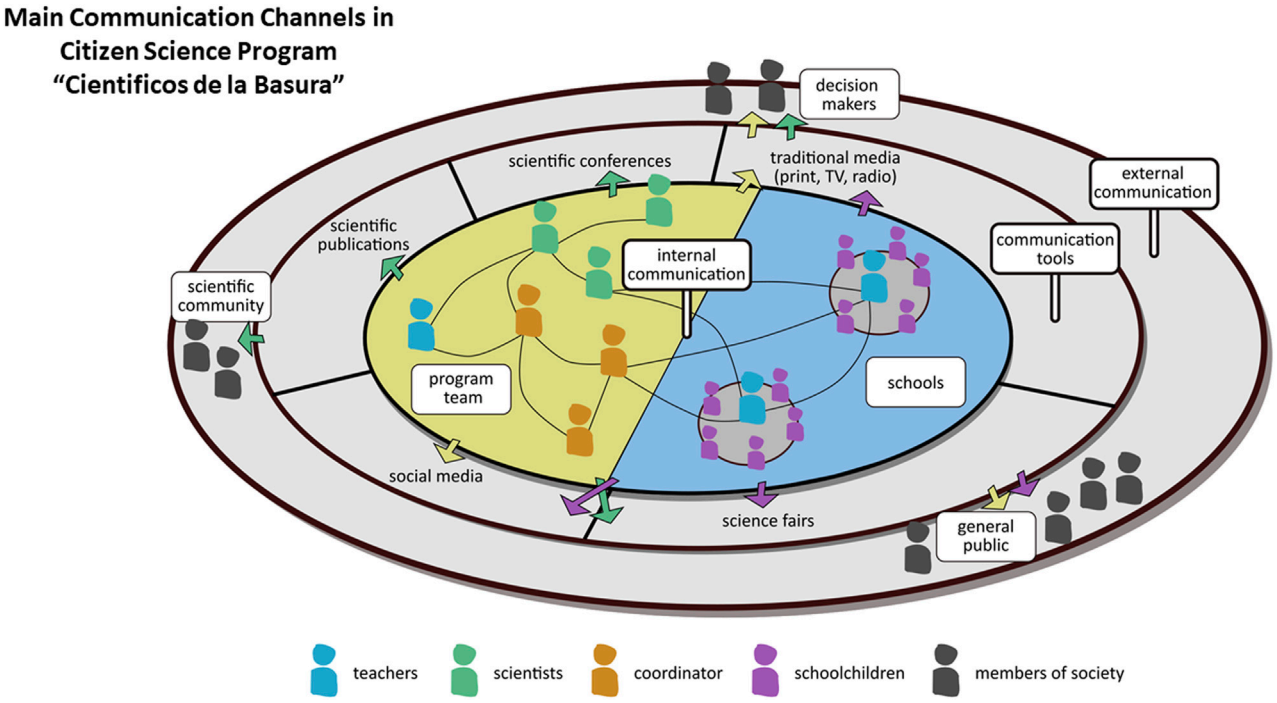

FIGURE 1
Organisational structure of the Latin-American Network of the citizen science program *Científicos de la Basura* with the program team (bright-yellow) and the school network (blue). Scientists marked with green, citizen science coordinators with ocher-yellow, educators (teachers) with blue, and schoolchildren with purple.

In order to reach the previously described program goals (learning, awareness, information, decision support), a key step has been to build a committed and trained teacher community. The individual research projects are primarily of the contributory citizen science type (Senabre Hidalgo et al., 2021), but the network offers a variety of activities to be involved in many more scientific processes, such as the design of educational materials and sampling guides and the dissemination of scientific results in science fairs, among others. Likewise, the program team is regularly evaluating and considering both the motivation of the participants (teachers and schoolchildren) and feedback regarding the program's scientific and education goals. In this contribution we share our experiences, highlighting which communication approaches were successful for being able to run a citizen science project initiative for 15 years and involving >12,000 schoolchildren and their teachers in research projects on anthropogenic litter. In this paper we focus on the first 2 years of the Latin-American Network (2018-2019), but we also mention briefly how the program adjusted in 2020 to the challenges of the COVID-19 pandemic. We further critically discuss aspects where we (and coordinators of other citizen science projects) could improve in the future.

The Latin-American Network and its research projects

Starting in 2018, the Latin-American Network has been initiated by the *Científicos de la Basura* program, and it is being maintained and coordinated by the program members since then. During the first semester of 2018, teachers and schools from the East Pacific coast were contacted and invited to participate in citizen science activities related to anthropogenic litter pollution (Figure 2). While the invitation was open to all schools along the Pacific coast of Latin America, we aimed at geographic representation, and therefore we often contacted collaborators and teachers from particular countries and coastal localities. In response to our public and personalized calls, 33 schools initially committed to participate in the Latin-American Network by signing a formal agreement letter (signed by the school director and the teacher). All activities were accompanied by the corresponding consent forms and the overall project was approved by the Scientific Ethics Committee of Universidad Católica del Norte (resolution F.M. N°10, 11 September 2018).

For each annual research project, the program team prepared four to five learning/training guides, two research guides, and two evaluation/outreach guides to walk the participants through how to analyse and share research results (Figure 2). These guides were in PDF format so that they could be easily printed by the teachers, and they were supplemented by short instructional videos. All of these materials and further support from the coordination team were free of charge for the teachers. During the project period, the school teachers were encouraged to implement all guides in the classroom and engage the schoolchildren in a variety of scientific processes. Although not all teachers had sufficient time to do all the activities (the end of the school year often approached before completing the evaluation/outreach guides), all participating schools at least conducted the research activities.

Teachers could apply for a basic research stipend/grant (up to about US$250), which they could use to pay for transport, food,

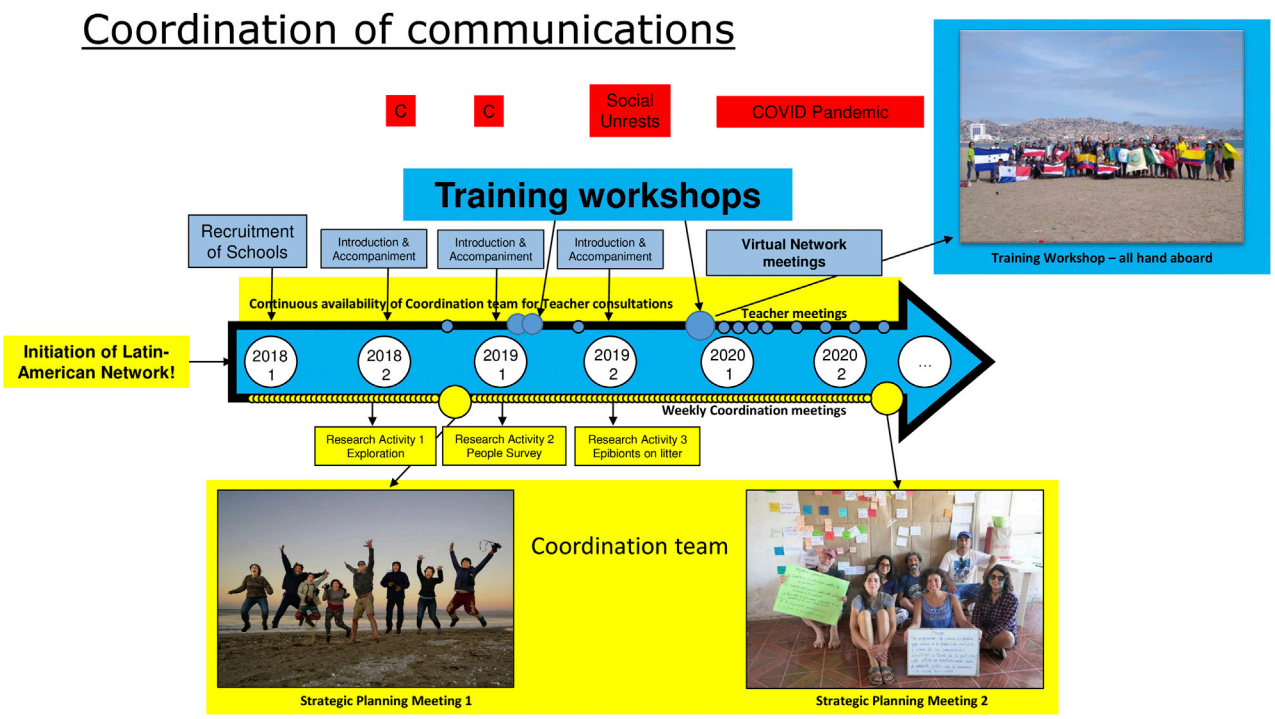

FIGURE 2
Project time line with major elements and events. Main project (large blue arrow) and complementary project (training workshops) are shown. On the lower edge of the main project arrow the internal communication of the program team is highlighted by strategic planning meetings (large yellow dots) and weekly design and organisational meetings (small yellow dots). On the upper edge of the main project arrow the teacher training workshops (large blue dots), and the regular network meetings (small blue dots) are shown. External factors affecting the network activities and communicational strategies are climatic events (C = hurricanes, rainstorms, floods), social unrest in Chile (October—December 2019), and the global COVID pandemic, shown in the upper part of the figure with red boxes. Working guides can be found at www.cientificosdelabasura.cl.

basic research materials (gloves, bags, *etc.*), or other needs such as photocopies. The program team also produced an environmental storybook (see https://zenodo.org/record/7081049), which was printed and then shipped to the teachers so that each participating child would receive a personal copy. The story is related to marine litter and its impact on sea turtles and served to increase schoolchildren's environmental awareness and to motivate them to participate in the citizen science activities.

In 2018/19, three research projects were conducted. Starting in August 2018, the participating schoolchildren explored their surroundings and shared general impressions of their schools, their locality and their beaches with the schoolchildren from the other countries through various formats, including hand-drawn pictures (working guides available at https://doi.org/10.5281/zenodo.5317138); exchange of pictures was mediated by the coordinating team via the project website. While the schoolchildren knew that they were participating in a research network about marine litter, these exploration activities did not specifically ask them to record litter. Interestingly, almost none of the hand-drawn maps from their daily path to school contained any litter, while many drawings from their local beaches did feature litter items (De Veer et al., 2022). In the first semester of 2019, schoolchildren visited public places and interviewed members of the general public to investigate the knowledge, perception, and attitude of the coastal population about marine litter (working guides available at https://doi.org/10.5281/zenodo.8396878). In the second semester 2019, the schoolchildren collected litter items on their local beaches and inspected these for epibionts, i.e., marine organisms that colonized floating litter items during their journey with the ocean currents (working guides available at https://doi.org/10.5281/zenodo.5906766). Throughout the duration of these research projects, the program team regularly contacted all the network teachers, was readily available for consultation, and accompanied them in the learning and research activities (Figure 2).

Communication strategy of the *Científicos de la Basura* program

1) Design and planning of research activities

1a) Internal Communication

The program team (four to eight people) met on a weekly basis to discuss all aspects related to the functioning of the program, including scientific questions, coordination, financial administration, data management, evaluation of results, and outreach activities. A main part of these discussions was dedicated to designing and planning of the research activities. Additionally, two strategic 3-day planning meetings were held during the period 2018–2020 (Figure 2). The first task of the project planning was identifying a clear scientific question and defining the minimum data requirements needed to respond this question. The design of the adequate research activities with detailed instructions for the participants (teachers and

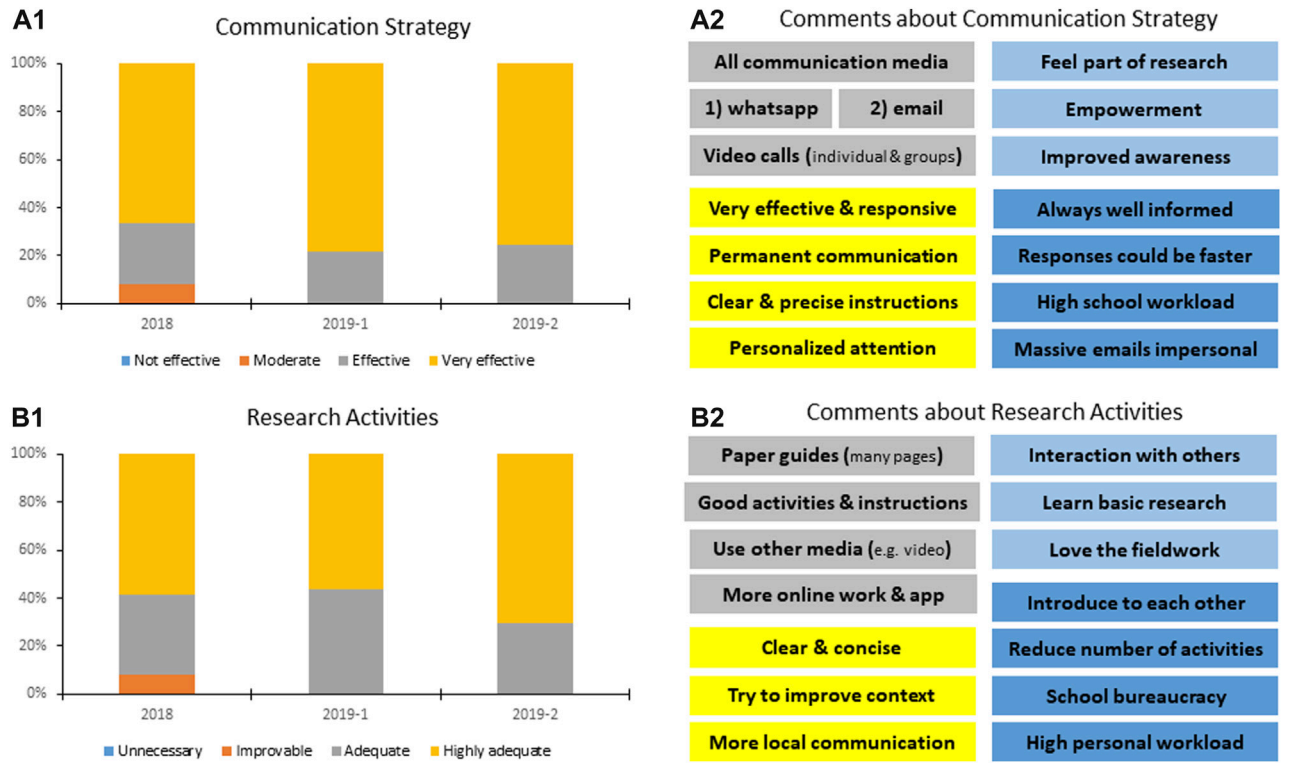

FIGURE 3
Percentage of teachers responding during the three research projects (one project each semester) to the questions **(A1)** "Do you think that the communication strategy that the program team has had with you has been effective?", and **(B1)**" Do you think that the activities suggested in the work guides are suitable to determine the local and environmental reality of your students, and in turn to learn about the realities of other countries?". Boxes on the right side **(A2, B2)** show for each of these two questions the main comments by the teachers referring to the communication tools (gray), role of the citizen science coordinator (yellow), schoolchildren (light blue), and teachers (blue). Number of teachers responding after each project were 24 (2018), 23 (2019-1), and 37 (2019-2).

schoolchildren) typically extended over several months and often required additional meetings of a smaller subgroup that internally agreed to be responsible for the respective scientific projects. During the design phase, the evolving research guides were regularly revised by all members of the program team. The results of the first field tests done by volunteers (e.g., one teacher with her/his course) were also evaluated by the entire program team, and problems with the research activities were identified and resolved. The continuous dialogue within the program team, consisting of the citizen science coordinators, the scientists, and the teacher (Figure 1), ensured feasibility and rigor of the final research activities, which are simple and straightforward as desirable for citizen science activities (e.g., Le Coz et al., 2016). While these discussions were sometimes intense and time-consuming, the resulting research guides have been applied widely, and they have generated essential baseline data about anthropogenic litter in Chile (Eastman et al., 2013; Hidalgo-Ruz and Thiel, 2013; Rech et al., 2015; Hidalgo-Ruz et al., 2018; Honorato-Zimmer et al., 2021) and in other countries (Kiessling et al., 2019; Gaibor et al., 2020; Garcés-Ordóñez et al., 2020).

1b) Teacher feedback

During the planning of each research project (see *1a Internal communication*), the citizen science coordinators consulted the teachers about their interest in participating and resources of their school, the local coastline, or litter items (e.g., presence of epibionts on litter items). This information gathered during these conversations was then taken into account during the project design. Once the research activities were taking shape, the teacher from our program team carefully revised the research guides and provided pedagogic feedback.

At the end of each research project (after each semester), we obtained both praise and constructive feedback from the teachers through questionnaires and personal conversations about the communication during the project development, the activity guides, and many other aspects (Figure 3). The suggestions were carefully evaluated and implemented in the new research projects whenever possible, leading to slight increases in the teachers' satisfaction with the program and the materials over time (for selected examples see Figures 3A, B). Many of the initial teachers continue to work with us to the current day.

2) Training and research activities

2a) Training of teachers before the research

Besides sharing the working guides and research materials with the teachers, we also conducted virtual trainings in form of multi-participant videocalls where background about the research motive was given and the rationale underlying the research question was explained. Due to the different time zones and personal schedules,

FIGURE 4
Examples of communication activities carried out by the schoolchildren participating in the *Científicos de la Basura* program. **(A)** Schoolchildren from "San José Rama Blanca" Educational Institution in La Gomera, Guatemala, sharing their research results with the educational community in 2019; **(B)** Schoolchildren from "República de Suecia N° 20959" school in Cañete, Peru, perform a representation with plastic bottles of the protagonists of the storybook "La Hermandad de las Tortugas" in 2019; **(C)** Peruvian national newspaper published in 2020 a press note written by schoolchildren of the "Beata Imelda" Peruvian-German School of Lima, Peru (link to the note: https://elcomercio.pe/corresponsales-escolares/historias/los-cientificos-de-la-basura-los-nuevos-guardianes-del-oceano-lima-noticia/); **(D)** Communication of research results by schoolchildren of "Modesto Sánchez Mayón" High School of Loreto, Mexico, in 2019. All images with corresponding permission.

not all teachers could participate in the same virtual meetings, and at least two separate videocalls (with 10–20 teachers each) were held. If a teacher could not participate in any of these group meetings, individual meetings were offered. During these videocalls, all the research steps were described in detail, and a virtual sampling was conducted that showed how to follow the research protocol in exactly the same way as it was required for their beach (e.g., showing a virtual beach with litter and counting virtual litter items). During the project period (2018–2020), we also conducted two *in situ* 1-week training workshops in Costa Rica (for ~20 teachers from Mexico and Central America) and in Ecuador (for ~20 teachers from Panama, Colombia, Ecuador and Peru). During these workshops, the teachers learned to conduct all the samplings to be developed during the project.

2b) Guidance for teachers during research

The citizen science coordinators maintained regular contact with the teachers during each project period (Figure 2), and they carefully monitored the progress of each teacher with their schoolchildren. For these individual communications, the coordinators used email, WhatsApp, phone, or videocalls, depending on the needs and preferences of each teacher/collaborator.

When the field sampling approached, the citizen science coordinators reviewed with each teacher the main steps for the research to ensure that teachers and their schoolchildren were well prepared for the research activity. During this period, the coordinators communicated with the teachers primarily through WhatsApp to enable rapid interaction. The coordinators knew the exact day and hour when each teacher did their sampling, and they made an effort to be available during those hours to respond instantaneously via WhatsApp for any consultations that would come up during the sampling. Upon completion of the research, the coordinators sent brief messages to the teachers and their schoolchildren congratulating them for the successful completion of the field sampling. When data were received, these were immediately checked for completeness and correct labelling (very similar to the process described by Dittmann et al., 2022). If there were substantial delays in data transfer (e.g., because the teachers were too busy with their regular schoolwork), the coordinators contacted the teachers to request the data and offer assistance, for example, by processing images or revising datasheets for sufficient resolution. In all communications, it was emphasized that the research is only completed when all data had been received, checked and archived. Using this intense and

personalized communication with each teacher, during the project years 2018 and 2019, we achieved high return rates (successful receipt of all data) of 80%–85% of all schools/teachers who had signed the participation agreement.

The main challenges occurring during the first 2 years of the work in the Latin American Network were climatic events (hurricanes or extended rainstorms in Central America), social unrests in Nicaragua, Colombia, Ecuador, and Chile, and the global health crisis (COVID-19 pandemic) (Figure 2), and the research projects had to be adapted to these external events. For example, weather-induced delays in the field research had to be accommodated (and the final evaluation/outreach activities could not be completed), and in the case of the social unrests in Chile, schools were not functioning and some samplings could not be conducted as planned.

3) Evaluation of data and sharing of results

3a) Data evaluation and interpretation of results

After completion of the research and submission of the data, the citizen science coordinators supported the teachers in the analysis of the data. In addition to the working guides describing the steps to analyse the data, the teachers were provided pre-formatted Excel tables that allowed the schoolchildren to enter their data and visualize their findings in summary tables and figures, similar to other school projects. If suitable, the coordinators also provided data from other participating schools, to which the schoolchildren could compare their own findings. The working guides for data analysis and interpretation also contained questions that encouraged critical thinking about their findings, and reflection on possible causes of plastic pollution.

After the sampling, the program team evaluated all the (unvalidated) data and prepared a first report on the research findings. These reports were typically prepared within several weeks after receipt of the last dataset, and they were first shared with the teachers but then also made available to the general public via the program website (www.cientificosdelabasura.cl).

3b) Guidance for communication

Following data evaluation and interpretation of results, the teachers and schoolchildren could advance to share their findings within their school or local community, or even with their scientific peers. Suggestions on how to participate in this scientific process were detailed in the evaluation/outreach guides and included science fairs, posters, and social media communications. The citizen science coordinators encouraged the teachers and their schoolchildren to choose the form of communication they felt most suitable (Figure 4). An instructional video provided hints about how to communicate their research findings (https://www.youtube.com/watch?v=A_QxnCiFPZM). If the teachers and their course decided to do this activity, the coordinator provided advice and shared information (e.g., from previous research projects of the *Científicos de la Basura* program) that could potentially be useful for the outreach materials the schoolchildren were preparing. Upon successful completion of the outreach event, the program team transmitted their congratulations to the teacher and their course. At the end of the research project all participating schools received a certificate of appreciation, which is sometimes requested and always cherished by the participants (see also Dittmann et al., 2023).

Discussion

Internal communications

The internal communications within the program teams are an essential element of all citizen science programs, which is especially true for school citizen science programs (see, e.g., Zoellick et al., 2012; Benichou et al., 2023; Bopardikar et al., 2023). Interestingly, in school citizen science programs on marine litter, the internal project interactions are rarely being mentioned when discussing the communication strategies of these programs. For example, Catarino et al. (2023) extensively describe the communication between the coordinating team and the schoolteachers and their schoolchildren. They also emphasize the outreach communication beyond their participating community, but they do not mention the internal communications within the coordinating team. Araújo et al. (2022) also focused on the communication between citizen science coordinators and the teachers, highlighting the importance of suitable materials and consideration of the learning objectives for the schoolchildren; it is evident that they paid close attention to the preparation of suitable materials and activities, but the internal conversations that certainly must have taken place were not explicitly mentioned. Also, van der Velde et al. (2017) highlighted primarily the training of teachers and schoolchildren without mentioning the internal communications within their team, but their study design had previously been thoroughly tested by professional scientists (Hardesty et al., 2017).

In this contribution we describe the close interaction between scientists and citizen science coordinators and selected teachers who evaluate and test the research activities. Several reports emphasize the importance of efficient communication between teachers and scientists (e.g., Zoellick et al., 2012; Atias et al., 2023a), which is essential to guarantee straightforward research activities that have an appropriate duration and are adapted to the motivation and capacities of schoolchildren (Bopardikar et al., 2023; Kali et al., 2023). This also ensures mutual benefits for teachers (learning goals) and scientists (contribution to research), which is essential for successful school citizen science projects (Kali et al., 2020; Roche et al., 2020). The activities initially designed by our program team (scientists, citizen science coordinators, teacher) have (i) led to multiple peer-reviewed publications providing marine litter baselines that are being used by decision-makers (e.g., Cristi et al., 2020), and (ii) been implemented by several other programs in Latin America and Europe (e.g., Kiessling et al., 2019), proving their usefulness and the value of the hard work during the design phase of the research activities. Another project used a comparable approach with direct interaction of the scientist in the classroom (Nicosia et al., 2014), where scientist and teacher formed a close alliance in order to guide one course of high school students in autonomous research. The authors describe their collaboration as follows: “In an effort to address the need for a guided framework, scientists and teachers participating in our study engaged in explicit discussions about the nature of science related to existing classroom curriculum. The purpose of these discussions was

to create a starting point for the investigation." (Gray et al., 2012). We suggest to make these internal communications within the coordination teams more explicit because they are the foundation of most successful citizen science projects (Zoellick et al., 2012; Sagy et al., 2019; Atias et al., 2023b; Benichou et al., 2023).

Scientists participating in citizen science programs are often highly motivated, having strong intentions to return scientific insights to society while simultaneously contributing to scientific progress (Rambonnet et al., 2019). When scientists themselves have a strong interest in responding the scientific questions being investigated, the following evaluation and interpretation of the findings will have a higher probability to result in the advancement of knowledge (e.g., Nelms et al., 2022; Dittmann et al., 2023; Jadallah and Wise, 2023).

Continuous communication with teachers

The citizen science coordinators from our program team are in regular contact with teachers and are always available to respond to questions during the main research phase. This is essential to guarantee the successful and correct application of the research guides, which is the first foundation for valid research data (see also Dittmann et al., 2022; Bopardikar et al., 2023).

The close involvement of the program scientists during the process also helps to resolve unexpected problems (e.g., due to climatic events) and take rapid decisions. For example, one consequence of the COVID-19 pandemic was that schools were not functioning and the research activities simply could not be conducted, similar as in a number of other citizen science programs during that period (e.g., Rose et al., 2020; Coldren, 2022). However, the strong sense of community in our project allowed us to develop alternative activities (e.g., Praet et al., 2023), and to readily restart activities when schools started to function again (e.g., Richter et al., 2021).

The intense communication between the citizen science coordinators and the teachers also leads to good knowledge about the professional and personal situation of each teacher. For example, the coordinators knew when climate or other external events led to delays in the realization of the learning and research guides, when a teacher was sick, and also when teachers conducted additional activities motivated by their participation on the network. The in-person training workshops created personal links and friendships among the teachers and scientists, promoting a feeling of community (see also Atias et al., 2023b). These personal relationships were especially relevant during the COVID-19 pandemic, when not only the program team but also many teachers faced unexpected challenges and personal hardship. Regular, appreciatory communication has also been shown to cause a stronger commitment by citizen scientists in other projects (Anderson et al., 2020; Rüfenacht et al., 2021; Nelms et al., 2022). It should also be highlighted that the citizen science coordinators have excellent interpersonal communication skills (confirmed by the evaluation surveys and personal conversations with the teachers), which helped to build and consolidate personal relationships among the program team and the teachers. These aspects are rarely being considered when discussing citizen science communications, yet they are the essential backbone of our network.

Rapid evaluation of data and preparation of outreach materials/activities

One of the major challenges for many citizen science programs is the time between collection of the samples/data (meaning in many cases the active involvement of the citizen scientists) and the proper evaluation of the results, which is essential to answer the corresponding scientific questions. This process leads to long delays of approximately 3 years or more between data collection and publication (Christie et al., 2021) and citizen science projects are no exception to this (Dittmann et al., 2023). During the first 10 years of the program, the average time between completion of the research and publication of the results was approximately 2 years, but this period has increased since the program became larger (now involving schools from up to 11 different countries) and more rigorous data validation steps were implemented. Naturally, the teachers and their schoolchildren are very keen to learn about the findings of the collaborative research projects, just as in many other citizen science projects (e.g., Richter et al., 2021). The careful design of the research question and simple methods of data collection allow for rapid preliminary evaluation of the data, and the program team prepared brief reports in Spanish for teachers and schoolchildren within two to 3 months after the data-collecting period had ended (freely available at www.cientificosdelabasura.cl). These reports are also frequently shared with the general public via social media (Facebook, Instagram) and also traditional media (e.g., newspapers).

Teachers and their schoolchildren are also supported in evaluating their findings and planning and implementing actions, which typically are outreach events, such as science fairs, public talks, infographics, or social media posts. Sharing data with the general public (and not only among themselves) is an important motivation for many citizens who have participated in a citizen science project (Ferster et al., 2013; de Vries et al., 2019). Often the communication of results are done by the program teams (e.g., Le Coz et al., 2016; Catarino et al., 2023), but the citizen scientists themselves can be excellent communicators of the research findings and conclusions. The schoolchildren who participated in the research projects of the Latin-American Network were very interested in sharing their results with others, and they were very creative in preparing different outreach materials and activities (Figure 4).

While schoolchildren are willing to engage in outreach and taking actions about the litter problem, participation in citizen science programs only leads to marginal increases in pro-environmental behaviors (Oturai et al., 2022; Wichmann et al., 2022), similar as in other environmental education projects (e.g., Praet et al., 2023). This is generally attributed to the short period of participation, highlighting the need for continued engagement of schoolchildren (and other citizen scientists) in these activities (Oturai et al., 2022; Wichmann et al., 2022; Praet et al., 2023).

Sharing scientific findings with others can be highly empowering to schoolchildren (e.g., Dublin et al., 2014) or strengthen place-attachment in volunteer participants (e.g., Toomey et al., 2020). If schoolchildren are able to engage their families or local communities, there is even the potential to reach and positively influence a wider audience (Vaughan et al., 2003). Another positive aspect of engaging citizen science volunteers in outreach activities is that they self-identify stronger with "their" program and might be more likely to continue in future research studies (Rambonnet et al., 2019). In addition, the volunteers might reach specific stakeholders, which the program team might not

easily reach, e.g., parents and local decision-makers (Vaughan et al., 2003; Rambonnet et al., 2019). If citizen science programs communicate effectively with decision-makers and other stakeholders, the probability that data and findings contribute towards the Sustainable Development Goals (SDGs) will increase substantially (Gacutan et al., 2023).

Critical aspects of communication

The communication strategy of the *Científicos de la Basura* program is very labor- and time-intensive, which has several implications. The attention given to individual teachers means that the number of teachers that the citizen science coordinators can accompany in their research activities is limited, typically around 30 to 50 teachers. These numbers are far below those of other citizen science programs collaborating with teachers and schoolchildren, which can reach hundreds of teachers (e.g., Kiessling et al., 2019) or thousands of schoolchildren (e.g., Oturai et al., 2022). However, the strong personal bonds developed during in-person workshops and the research projects create a strong mutual commitment both in the program team as well as in the teachers (e.g., Rüfenacht et al., 2021). This was demonstrated during the COVID-19 pandemic when program team and teachers met regularly in videocalls (first on a weekly basis, later on a biweekly or monthly basis) offering mutual support during this time of personal hardship and professional stress, which especially many teachers experienced (Rasmitadila et al., 2020; Sigursteinsdottir and Rafnsdottir, 2022). During these meetings we occasionally discussed scientific publications on the marine litter problem and even invited colleagues from other countries to share some of their insights with the teachers from the network. After sharing concerns about the wellbeing of their schoolchildren during these meetings, one teacher was inspired by one of those publications (Schofield et al., 2020) and encouraged the program team to develop an app that allows schoolchildren to tell stories on the phone or computer; 80 schoolchildren then used that opportunity and shared their views and ideas about marine litter (Praet et al., 2023).

The intense communication between citizen science coordinators and teachers as being practiced by our program has important time requirements (e.g., Benichou et al., 2023; Jadallah and Wise, 2023), which may not be feasible for other citizen science programs. In the *Científicos de la Basura* program this approach has evolved over time, taking into account the high workload of teachers in Latin America. The close communication and careful adjustment of the research projects to the realities of the school teachers helps them in achieving the learning objectives for their schoolchildren. Certainly, there are still some difficulties that our program needs to overcome, such as incorporating professional communicators (i.e., journalists) and lowering the high personal strain on the fully committed program coordinators who often interact with teachers outside of regular working hours. Nevertheless, we suggest that other citizen science programs working in similar socio-economic environments might benefit from similar approaches to those employed in our program: engaging in close communication and receiving regular feedback from their volunteer collaborators, whether these come from schools or other societal backgrounds.

Conclusion and recommendations

In this contribution we highlight the importance of internal communication within citizen science programs, especially the fluent dialogue between scientists and citizen science coordinators within the program team. The outcomes of these continuing interactions also strongly influence the communication with the teachers and schoolchildren (creating sense of community), and with the wider audience being reached by a citizen science program. The successful communication strategy of our program (internal communication and teacher communication) offers a number of advantages that could be recommended for other citizen science programs (Table 1), but it needs

TABLE 1 Recommendations for communication processes in citizen science programs based on experiences in the *Científicos de la Basura* program that contributed to achieve the program goals.

- Program team consisting of scientists, citizen science coordinators and a teacher, holding regular task-oriented meetings for efficient internal communication that guarantees successful research projects
- Focus on building strong personal relationships with participating teachers and therefore building a caring community supporting each other beyond the scientific goals of the program
- Conveying the worth of teachers' opinions, which not only enables to improve the research activities in the form of critical feedback, but occasionally leads to complementary activities
- Offer a mix of activities besides a core scientific activity the participants can be involved in, according to their interests, motivation and resources, for example, outreach activities or simply engaging materials such as an illustrated story book
- Offer activities that empower the citizen scientists and support them conducting these activities, e.g., outreach activity-guide
- Use communication tools that participants (in this case school teachers) are already familiar with. Use a variety of communication channels to adapt to the need of participants. Be readily available and have the team resources to be available
- Focus on the science: communicate the importance of the common research goal, emphasize that educational and scientific goals are interlinked in citizen science projects, and carefully listen to the participants in terms of need for assistance
- Use a ritual to convey the importance of being involved in the citizen science activity to all parties, for example, by signing a commitment agreement at the start of the project
- Prepare a preliminary research report as soon as possible (within 2–3 months of concluding the field research) as the participants are keen to learn about their collaborative findings
- Mutual praise between all parties involved, here among the program team, teachers and schoolchildren
- Emphasize the need for continuous and sufficient financial resources towards funding agencies as an established and dedicated citizen science community requires intensive communication at different levels

to be kept in mind that this strategy is highly labor-intensive, which requires substantial time and financial resources (personnel costs). In countries with other socio-economic backgrounds where teachers may have more time to prepare their classes and thus have better opportunities to integrate new materials, citizen science programs might work with less communication. However, in order to generate a sense of community, strong commitment and even willingness to change behaviors (e.g., related to plastic consumption), intense communication between program teams and volunteers might be required.

It should also be emphasized that the intensive and personal, customized communication as practiced in our program results in strong commitment of the participating teachers, which is also reflected in a significant personal commitment of the program team. We conclude that communication and commitment are closely related to each other and build the foundation of successful citizen science programs.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

MT: Conceptualization, Funding acquisition, Supervision, Visualization, Writing–original draft, Writing–review and editing. JB: Writing–review and editing. MD: Writing–review and editing. DV: Writing–review and editing. SD: Writing–review and editing. VG-T: Writing–review and editing. GA: Visualization, Writing–review and editing. DH: Visualization, Writing–review and editing. TK: Visualization, Writing–review and editing. AL: Writing–review and editing. N-LX: Writing–review and editing. PN: Writing–review and editing. JS: Writing–review and editing. NV: Writing–review and editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Financial support received through PhD fellowship to DDV (CONICYT-PCHA/Doctorado Nacional/2018–21181806), Marine Conservation Fellowship to MT from the Pew Charitable Trusts (under grant agreement number 00031733), European Union's Horizon 2020 Research and Innovation Program, MINKE project (under grant agreement number 101008724), Global Challenges Research Fund (NE/V005448/1), Project Fondo Chile (Ministerio de Relaciones Exteriores y la Agencia Chilena de Cooperación Internacional para el Desarrollo (AGCID) in alliance with the United Nations Development Program (UNDP), the Federal Ministry of Education and Research of Germany (SD, TK), Kiel University - "Zukunftsvertrag Studium und Lehre stärken" (TK).

Acknowledgments

Foremost we would like to thank the teachers who are the pillars of our network. They keep us grounded and continuously guide us to become better communicators. Three reviewers offered many constructive suggestions that helped to improve this manuscript. We are very grateful to Julia McElhinny for carefully editing the final manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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