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A technical–scientific content management system on water reuse as an environmental education tool: the experience of a Portugal/Brazil partnership

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ABSTRACT

This study presents the *Instituto Reúso de Água* (IRdA) as a high-quality environmental education tool. The results measured the reach of IRdA's direct (webinars, learning series, and mentoring) and indirect (technical–scientific repository and the production of more easily assimilated data) educational actions since its conception (Period 01), operation of the platform (Period 02), and operation of IRdA (Period 03), through its digital platform and social media. The direct actions proved to be effective in disseminating knowledge, highlighting a preference for the topic 'regulation' and adherence to content produced in different video formats. On the other hand, the indirect actions showed that the scientific approach is less accessed due to its complex language. However, when presented into more accessible data, scientific content gains confidence and can be of great relevance for the transformation of society. The results corroborate the current trend of greater educational reach in a free and digital format to build a society truly committed to water reuse and its more efficient management.

Key words: collective knowledge construction, educational actions, educational videos, sustainable development, water conservation

HIGHLIGHTS

- Water reuse is a key tool in efficient water management.
- The primary global challenge in water reuse adoption is overcoming the 'Yuck Factor'.
- Digital content is an effective tool for raising environmental awareness.
- Instituto Reúso de Água's educational efforts through social media are highly efficient in spreading water reuse content.
- Personal access to content leads to the dissemination among both professional and personal networks.

GRAPHICAL ABSTRACT
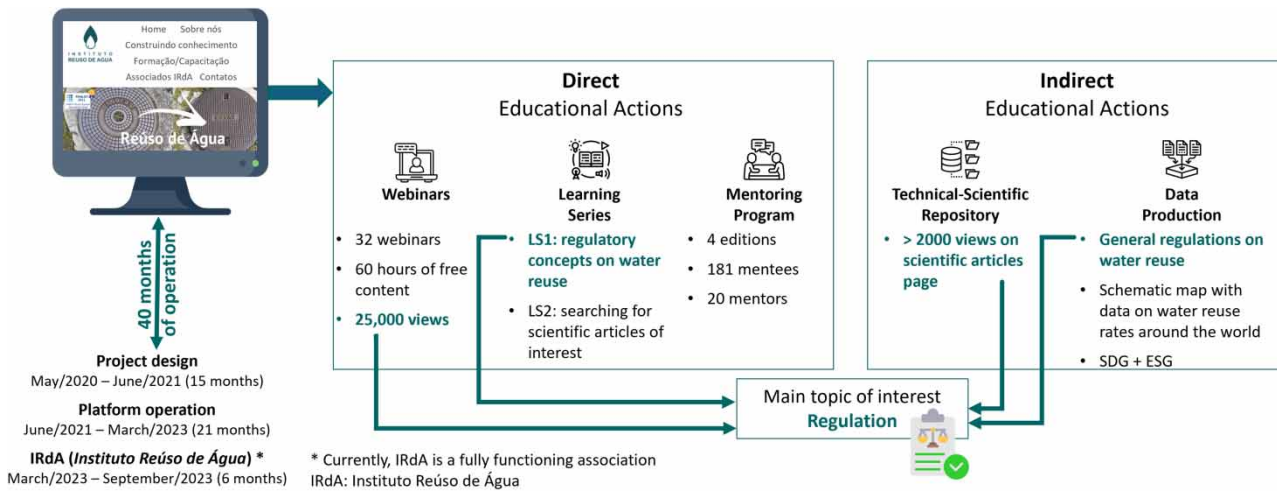
1. INTRODUCTION

The consumption of water around the world is increasing at alarming rates (WWAP 2017). The same is happening with the generation of effluents, which, due to inefficient global management, is leading to higher levels of pollution in water bodies. According to Jones et al. (2020), only 50% of the sewage generated in the world is currently treated.

To exacerbate this water insecurity, climate change is imposing major challenges for water management, which is being confronted with extreme temperatures, prolonged droughts, and flooding. To respond to these challenges, sustainable development requires more assertive actions, which result in more efficient water management. Sustainable Development Goal 6 (SDG6), established by the United Nations in 2015, aims to ensure the availability and sustainable management of drinking water and sanitation for all. Actions are needed to achieve this goal, including more efficient water management, which necessarily involves the rational use and reuse of sustainable water sources. Water reuse is one of the main instruments for efficient water management (Mukherjee & Jensen 2020). However, according to Jones et al. (2020), it is estimated that only 11% of the world's treated sewage is used in a planned way, although there are some countries with very high rates of reuse (Santos et al. 2022).

Several factors are decisive if higher rates of water reuse worldwide are to be achieved, such as integrated water and wastewater management, structured regulation, adequate planning and investment, adapting wastewater treatment technologies to different uses, and minimizing rejection of recycled water (Angelakis et al. 2018; Santos et al. 2022). Mukherjee & Jensen (2020) highlight rejection of recycled water (Yuck Factor) as the main challenge for the generalization of water reuse practices worldwide.

The studies carried out on the determining factors for the acceptance of the practice (mainly for potable reuse) state that the main factors in addition to specific knowledge on the topic are related to educational level, demographic conditions, trust in the institutions involved, and the sense of shared responsibility between the public and water management sector (Furlong et al. 2019; Mukherjee & Jensen 2020; Rosenberg Goldstein et al. 2024). Considering sophisticated neurocognitive measures, Rosenberg Goldstein et al. (2024) pursued a broader goal of demonstrating how knowledge about water reuse can increase the willingness of individuals to use recycled water. The authors concluded that understanding the most effective approaches for water reuse education could lead to increased acceptance of this important climate adaptation practice. However, Chfadi et al. 2021 demonstrate a high acceptance of water reuse for applications with low human contact, while applications involving direct or indirect consumption, or contact with the skin, are less accepted. This statement is related to the perception of the risk of contamination on the part of users.

In this context, a transparent awareness-raising process is needed with all those involved to establish a relationship of trust between producers and users of recycled water (Hartley et al. 2019; Mukherjee & Jensen 2020), in addition to the application of more efficient educational processes (Rosenberg Goldstein et al. 2024).

At this point, it is necessary to break old patterns of knowledge that define water management as a linear process. However, bringing understanding to a new paradigm that embraces the concept of the circularity of water is not a simple task. It

involves engaging with the 'One Water' concept, which states that water is one, regardless of how it looks or the 'history' it carries (Angelakis *et al.* 2018). This scenario involves the transformation of the society, which will take place over the long term but needs to be initiated and pursued with persistence. According to Water Europe (2020), efficient water management, which involves several factors in addition to water reuse from treated wastewater, will only be achieved with a 'water smart society'. To achieve this, breaking down old conceptual patterns requires a more efficient dynamic in terms of environmental education, with modern, accessible, and inclusive tools.

Digital content has gained prominence as an efficient tool for raising awareness among different actors (Zhang *et al.* 2017). In this regard, Chfadi *et al.* (2021) suggest that decision-makers use the right combination of messages, media, and information content to provide clear and accurate information to citizens, to encourage acceptance of the practice.

To encompass representatives of all actors in the society across the board, the digital content platform that is the focus of this study was conceived in 2020, launched in 2021, and institutionalized in 2023 as Instituto Reúso de Água (IRdA) (it means 'Water Reuse Institute', in English). It is an independent and voluntary technical–scientific partnership between Portugal and Brazil, with the mission of acting creatively in the production, management, and sharing of technical–scientific content related to water reuse. According to Massarani & Araripe (2019), science is fundamental to the development of society. However, in some regions, such as Brazil, the general public has little access to scientific findings and IRdA aims to promote scientific advances to support the development of safe and responsible reuse practices.

There are many institutions of this type in the world. However, to our knowledge, there are no other institutions that specifically address the topic of 'water reuse', in the technical–scientific context, either in Brazil or in Portugal. We also do not know of previous studies that have used the results of its scope in a scientific article, as a mechanism to guide future approaches, in its strategic planning. In this sense, the study is a high-level tool to suggest and validate the paths to be followed in modern and more assertive educational processes, related to topics as complex as the safe and responsible application of water reuse, as well as its acceptance among users and other stakeholders.

Given the above, the study aims to evaluate the creation, development, and application of the IRdA as an environmental education tool on the rational use and water reuse, with a view to sustainable development, based on the scope of its structured and integrated educational actions, from its conception.

2. METHODS

This study is presented in two stages. The first covers the design of the project, in which the entire process of creating and developing the environmental education tool is presented. The second shows the structuring of the metrics for evaluating the reach of the educational content, based mainly on its visibility on a digital platform (website), and social networks.

2.1. Stage 1. Creation and development of the environmental education project

The IRdA was created as part of a technical–scientific partnership between Portugal and Brazil. It is an environmental education tool related to rational use and water reuse, aimed at building collective knowledge to leverage the water reuse practice safely and responsibly in both countries. The content produced, managed, and shared by the IRdA is completely free to access, is constantly updated, and aims to reach all the actors involved in the issue, such as decision-makers, technicians, academics, system operators, and the society in general. The content produced and managed as part of IRdA's educational activities is mostly available in Portuguese, the official language of the project's two partner countries.

The creation of IRdA spanned 40 months and occurred in three distinct phases, as described below:

(1) Project design: The project was conceived in May 2020, during the COVID-19 pandemic, based on a shared understanding of the need to share technical–scientific material on the subject voluntarily. At that time, online events were gaining prominence, so it was possible to start this movement by organizing webinars and short online courses. It was a time when the world was confined and looking for training and updating material.

(2) Platform operation: Based on the understanding that this path was possible, a content management system was developed, based on a digital platform (reusodeagua.org), which was launched on 17 June 2021, on the International Day to Combat Drought and Desertification. The project was set up with the founders' resources, without any public or private subsidies. In just a year and a half of operation, with the development of different educational actions, the platform achieved such visibility that it led to the next phase of the project.

(3) IRdA: In March 2023, new experts (technical and academic) living in Portugal and Brazil were added to the executive group, and the digital platform was institutionalized in the form of a nonprofit organization. IRdA currently has associate members (individuals and institutional) as well as institutional partners, who together finance the platform for the common good.

To reach the various players in society involved in the issue, IRdA aims to disseminate knowledge in a language accessible to different players based on a structured line of reasoning for building collective knowledge. In this sense, the project develops educational actions with both a direct and indirect reach. In the first case, the actions are directly assimilated by the general public insofar as they require active participation between communicators and interlocutors; the second is the production of technical–scientific content that does not require active participation by the public and thus contributes indirectly to the construction of knowledge.

2.1.1. Direct educational actions

Direct educational actions are divided into webinars, learning series, and mentoring and have included the following:

- Thirty-two webinars made available by the IRdA, which were created by its members and are hosted on different digital learning channels [Tech Ideias (TI), Salomão Medeiros (SM), Instituto Brasileiro de Educação Continuada (INBEC), it means 'Brazilian Institute of Continuing Education', in English, and ABES Conecta]. Different subjects relating to the topic are covered in a general way, including practical, operational, regulatory, technological, economic, management, and governance aspects, as well as modern and current concepts, different types of water reuse, potential studies, SDG, and Environmental Social, and Governance (ESG) tools.
- Two learning series, which were conceived, built, and made available by the IRdA, with the aim of presenting general content that can be instantly assimilated. The learning series comprise short videos that present basic concepts structured and integrated with other institutional actions to support the general construction of knowledge.
- The Mentoring Program, which was carried out in four editions, lasting for a total of 14 months. It involved national and international mentors, reaching a very diverse audience, to empower the participants through an exchange of knowledge and experiences between the mentees themselves and between the mentees and the mentors.

2.1.2. Indirect educational actions

Indirect educational actions are divided into the composition of a technical–scientific repository and the production of data that are easier to assimilate as follows:

- The repository features scientific articles related to the topic, published in national and international journals, as well as technical papers presented and published at national and international conferences. All of this content is subdivided into two groups: (i) works developed by the founding members of the IRdA, who are academic and technical practitioners; and (ii) works developed and published by other international authors, considered by the founders to provide research or content relevant to the state of the art on the central theme. It should be noted that all the works made available on IRdA's digital platform lead directly to the platforms of the scientific journals where the original articles are published.
- Data are produced to facilitate access to important information by summarizing the information and presenting it in a more user-friendly format. Flowcharts, tables, and images are produced specifically for this purpose. In this context, the most relevant materials were selected for this article, such as general regulations on water reuse; a schematic map with data on water reuse rates in different countries; and the relationship between the SDGs and ESG, and water reuse.

2.2. Stage 2. Structuring the metrics for evaluating the reach of educational content

All the content presented above was primarily evaluated based on its visibility on the IRdA's website and social networks over the timeframe established for the research (from May 2020 to September 2023). The metrics for each action are shown in Table 1.

Of the educational content, only webinars and mentoring sessions generated online meetings, where guests were part of the executive network of IRdA. In both cases, audience participation was encouraged: YouTube chat for webinars and through voice and chat for mentoring. Furthermore, the webinars were conducted on other channels, with the founders of IRdA solely involved in event organization; promotion was the responsibility of the channel host. For this reason, participation metrics, except for views, were not recorded.

Table 1 | Metrics used to evaluate the reach of IRdA's educational content

| Content	Metrics
Webinars	The views of all the webinars available on the IRdA website were counted using the official figures provided by YouTube. As Supplementary Material, a spreadsheet is available with the main information on each webinar (title, date, access link, and host educational platform).
LS	The LS comprises short videos, and the reach was calculated based on the official number of views for each video, made officially available by YouTube.
Mentoring Program	Invited mentors were counted, in addition to the mentees enrolled in each of the four editions. However, it should be noted that one of the main objectives of the Mentoring Program is to train multipliers to disseminate learning to their professional and personal peers. In this sense, the reach of the Mentoring Program is far greater than is accounted for here. However, measuring this reach would be very subjective and for this reason, this extrapolation has not been included.
Repository technical–scientific	By managing the website account, it is possible to view the accesses to each of the items available on the page. Thus, annual and total accesses were counted for both the technical–scientific articles produced by the IRdA team and the scientific articles by other authors considered relevant to the state of the art of the general topic.
Data Production	All the material relating to Data Production was linked to posts on the IRdA's social networks. Thus, engagement was counted based on views, likes, and shares on both Instagram and LinkedIn. In addition, views of this content on the IRdA website were also counted through account management.
General content (website and social networks)	To provide an overview of the website's general visibility, monthly views and visits were counted from the test period before its launch. It was also possible to observe the number of views in different countries around the world, in addition to the two countries of origin of the IRdA (Brazil and Portugal).
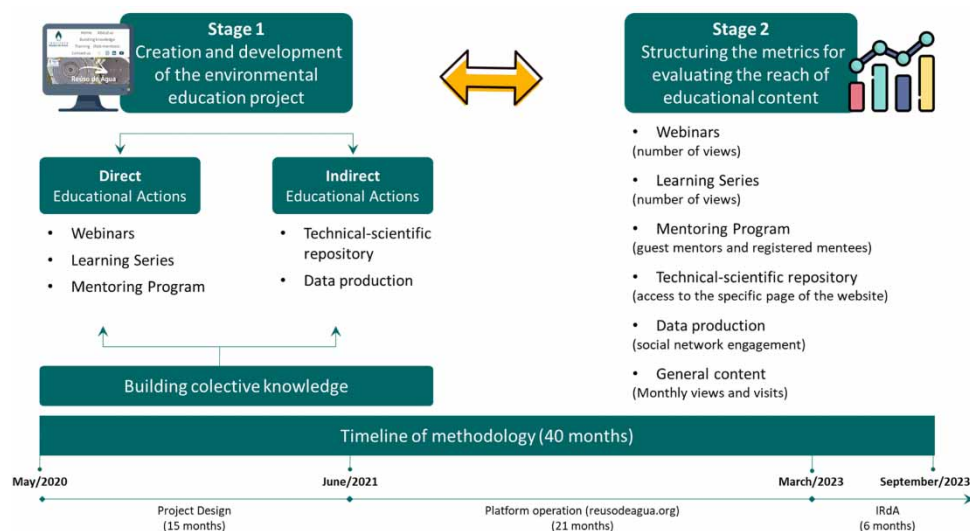
Figure 1 | Flowchart of the study methodology.

Figure 1 shows a flowchart with the main aspects related to the methodological development of the study as well as the main elements of the methodological time record.

3. RESULTS AND DISCUSSION

The results are presented according to the metrics established in Table 1 for each of the direct and indirect educational actions. Furthermore, the 'limitations and lessons learned' are discussed and highlight these issues and support similar experiences in different geographic regions or thematic contexts.

3.1. Direct educational actions

Over the course of the research period, 32 webinars were held on various subjects. Figure 2 shows the visualizations of each of them, in chronological order, the specific information that can be found in the Supplementary Material. It is also possible to see the occurrence of the webinars in the different periods of the project (project design, platform operation, and IRdA) and the variability of the views in the same periods over the total period.

The 32 webinars were broadcast live and account for a total of more than 60 h of free content, approximately 25,000 views (with an average of 765 views) and 107 (speakers) involved. There is great variability in the total views of each webinar, with Webinar 13 standing out with a maximum of 2,575 views and Webinar 27 with a minimum of 49. In Webinar 13, the topic of discussion revolves around regulation, whereas Webinar 27 delves into scientific research methodology. This starkly illustrates the disparity in interest between these subjects.

IRdA's design period and operational period show more stability in terms of views. However, the platform's period of operation, in times of re-opening of the COVID-19 pandemic lockdown process, shows greater variability, and this pattern also applies to the total period of the timeline. Some factors can be considered relevant in analyzing this variability, such as the time/period and the central issue.

With regard to 'time/period', it was to be expected that there would be a greater number of views of webinars broadcast more recently, i.e., at the beginning of the research timeframe. In fact, the average number of views for the first half of the webinars was 1,068; for the second half, 461. To calculate these intermediate averages, the first half was taken up to Webinar 16, dated 26 October 2021, covering the complete design phase and part of the platform's operation; the second half covers the other part of the platform's operation and the functioning of IRdA.

There was a high concentration of views at the beginning of the timeline during the project's conception period. The first five webinars, with an average of 1,653 views between them, took place during the main period of global lockdown due to the COVID-19 pandemic. According to Cesana *et al.* (2022) and Mehta & Maniar (2023), the COVID-19 pandemic has significantly boosted access to and sharing of information, highlighting the importance of digital content as a vital learning and awareness tool. This trend toward digital access has not only been limited to the lockdown period. Frazier *et al.* (2014) report (prior to the COVID-19 pandemic) that the significant number of people connected has been increasing over time, driven mainly by the possibility of interaction and the exchange of information. Also, according to Severo *et al.* (2019), the digital environment provides a direct relationship with other users and can be adapted to other day-to-day commitments. Currently, during the IRdA's period of operation, the average number of webinar views has fallen considerably and stands at 384. This reduction was to be expected since the announcement of the end of the pandemic has brought the world's population to a new way of life in which, in general, work overload is a major factor (Mehta & Maniar 2023).

When considering the central subject factor of the webinar, those with the most views address the topic of 'regulation'. According to Angelakis *et al.* (2018) and Pathiranage *et al.* (2024), comprehensive and adequate regulation of water reuse is one of the main challenges when institutionalizing the practice in different regions of the world. In this sense, it is understood that the public is more interested in this knowledge, hence the large number of views on this topic. The three webinars with the highest number of views are 13 (2,575), 2 (2,057), and 4 (1,877). They all deal with the topic of 'regulation'. Webinars
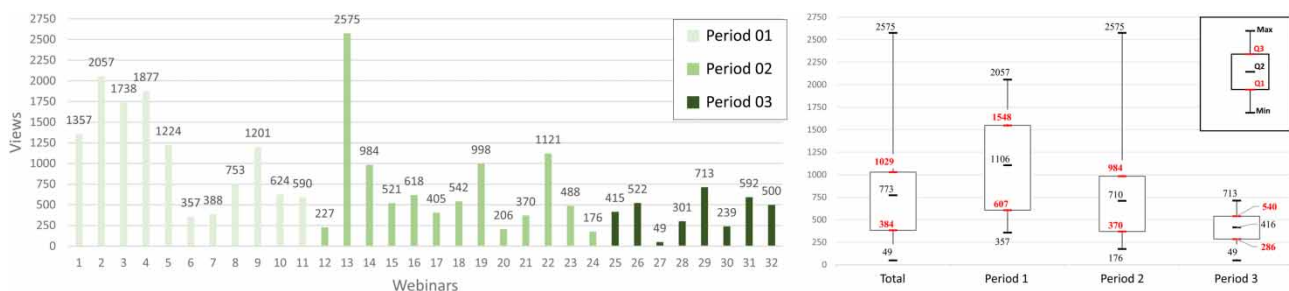

Figure 2 | Webinar views with the participation of IRdA members and variability of views in each of the periods. *Note*: Period 01 – Project design; Period 02 – Platform operation; Period 03 – IRdA. Min, Minimum; Q1, First quartile (25%); Q2, Second quartile (median); Q3, Third quartile (75%); Max, Maximum.

2 and 4 took place during the global lockdown due to COVID-19, but 13, the most viewed, took place during a period of extended pandemic restrictions.

In this regard, an important action by the IRdA, which began in the second half of 2023, in partnership with the *Instituto Nacional de Ciência e Tecnologia Estações de Tratamento de Esgotos Sistentáveis – INCT ETEs Sustentáveis* (it means 'National Institute of Science and Technology in Sustainable Wastewater Treatment Plants', in English), was the development of the Webinar Series, with one episode per month on this topic. Webinars 29, 31, and 32 shown in Figure 2 refer to this program and have more than 1,500 views in total until the end of the research timeframe (2 months).

Other topics are also worth highlighting. Webinars 1, 3, and 17 cover the history of water reuse practice, with an average of 1,167 views between them. Webinars 5 and 8, on the topic of 'water reuse potential in Brazil' together achieved almost 2,000 views in total. Conversely, the topic of 'developing scientific articles' achieved a very low number of views. This is the case with Webinars 10 and 27, where the latter had the lowest number of views (49) of all.

According to Moraes & Torre (2004), teaching methodologies that allow knowledge to be built up over time are more effective for learning than those that present ready-made concepts in written documents (such as books, articles, and technical–scientific documents) or spoken documents (such as webinars and podcasts). Furthermore, concepts acquired in a visual format are also more efficient from the point of view of the teaching–learning process (Moran 2007). Rosenberg Goldstein *et al.* (2024) highlight the efficiency of videos in building specific knowledge about water reuse and consider them as an important tool to corroborate users' acceptance of the practice. In this sense, the IRdA uses short videos (up to 5 min in length) in its *learning series*, in which concepts are built up as the video is played. In a complementary way, videos on the same subject, organized in a series of episodes, structure a line of reasoning on a specific topic.

As already mentioned, one of the main objectives of IRdA is the construction of collective knowledge. In this sense, the learning series is important for achieving this goal and permeates the Institute's other educational actions as a basis for the structuring the general content. This action mainly involves users and followers who are still in the process of consolidating their concepts on the subject.

The previous discussion on webinars demonstrated the audience's strong interest in deepening regulatory concepts on water reuse. In this sense, the first Learning Series (1LS), made available in March 2023, addresses this topic in four episodes: (i) introduction, (ii) water quality, (iii) treatment technologies, and (iv) risk assessment of microbiological contamination. The second Learning Series (2LS), made available in June 2023, covers tools for searching for scientific articles of interest in four episodes: (i) basic concepts, (ii) types of articles, (iii) searching for articles, and (iv) what to extract. This theme was covered because the IRdA strives to disseminate technical–scientific content on the subject that, in general, society has difficulty accessing and understanding (Massarani & Araripe 2019).

The total number of views for each of the two learning series (137 and 98 views, respectively) is shown in the graph in Figure 3. While the pictures on the covers in Figure 3 are in Portuguese, as they are the original covers, the explanation, general title, and episode titles are described below.

Despite the lower number of views for 2LS compared to the 1LS, it can be still deemed satisfactory in relation to the others. It should also be noted that the 1LS has been available for 6 months, while the 2LS has only been available for 3 months.

The last direct educational action adopted by the IRdA is the Mentoring Program. According to Wang *et al.* (2010), this type of program aims to link a specialist in a particular subject with a developing professional, providing professional and academic support. This model is widely recognized and advocated as a form of support and preparation for students at different levels of education (Bryant-Shanklin & Brumage 2011; Mikkonen *et al.* 2022).

The IRdA is keen to integrate the different players in the sector to enable them to engage and exchange experiences. The IRdA Mentoring Program aims to provide technicians, academics, and the society in general with modern and contemporary information, as well as more common concepts, but in a practical day-to-day environment. This interaction between more experienced players (mentors) and young technicians or professionals starting their careers in the sector (mentees) brings comfort and supports management paths.

During the period covered by the research, four editions of the Mentoring Program were held, covering a variety of subjects (refer Table 2), with experienced mentors, including international professionals, to allow young people working in the field to come into contact with experienced professionals. In all, more than 180 mentees had the opportunity to integrate and improve in 15 h of free meetings moderated by IRdA members.
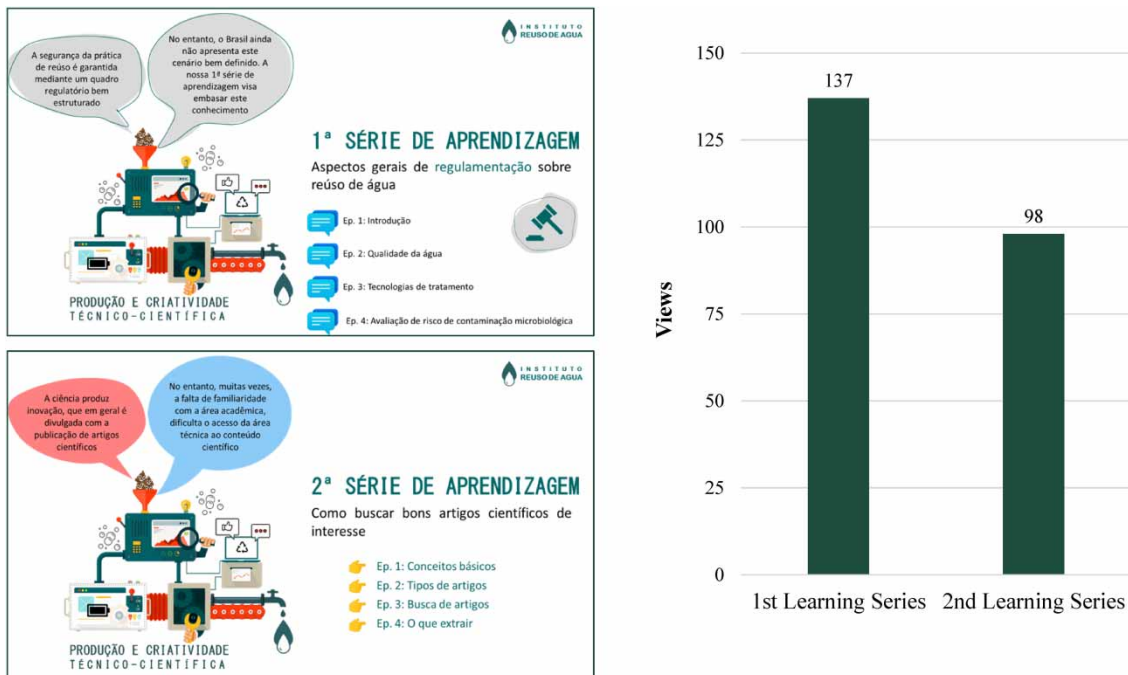
Figure 3 | Presentation cover and visualization chart for the LS.

Table 2 | Mentoring program themes, period, and number of mentors, mentees, and meetings in the four editions

Mentoring Program	Subject	Period	Mentors	Mentees	Meetings
1st edition	Paths of water reuse research	August to December 2021	12	62	5
2nd edition	Recycled water as a product	March to June 2022	4	49	4
3rd edition	Types of water reuse: agricultural, industrial, and urban	September to November 2022	3	66	3
4th edition	How to understand a scientific article	April to June 2023	1	4	1

The first three editions focused on technical subjects, involving professionals from different sectors, to share experiences in a multi- and interdisciplinary environment. In these cases, the number of participants was much higher than in the fourth edition, which focused, like the 2LS, on the general understanding of scientific articles on the subject.

Thus, the Mentoring Program facilitated the participants' capacity building through an exchange of knowledge and experiences among the mentees themselves, as well as between them and the mentors. It can be said that this was the project's objective. With each edition, it was possible to refine the dynamics involving the participants' relationships.

A limitation of this part of the study lies in the lack of information about the general characteristics of the public since we did not initially aim to evaluate the profile of the participants. In this sense, we did not characterize this sample during the registration period.

3.2. Indirect educational actions

One of the major challenges pointed out by the scientific community about the dissemination of the practice of water reuse is the natural rejection caused by the psychological repulsion of the practice, as it involves the use of effluent, even if it has been treated (Santos *et al.* 2022; Bachi' *et al.* 2023; Gullberg *et al.* 2023). However, it is also known that trust in scientifically proven results generates more confidence and can corroborate the increase in acceptance rates (Lazarova *et al.* 2003; Buyukkamaci & Alkan 2013; Tortajada & Nambiar 2019).

With the firm purpose of disseminating scientific advances in the practice of water reuse, the IRdA has an important space on its website that functions as a repository of scientific articles of interest, produced both by the IRdA's team of researchers (Our Articles) and by other renowned researchers in the field (Other Articles).

Throughout the research period, IRdA members published 23 articles in indexed journals in Portuguese and English and 8 technical papers presented at national and international conferences. All of them deal with issues related to efficient water management and water reuse. This action aims to provide scientific findings to deepen the debate. However, the articles by other researchers encourage international debate and bring important reflections to the national scenario. In this context, the repository includes 28 relevant articles that address the main topics related to water reuse at an international level, such as regulation, potable reuse, microbiological risk assessment, case studies around the world, gray water reuse, economic aspects, and rejection.

The reach of this content was calculated using the views of the two pages of the website (of 'Our Articles' and 'Other Articles'), as can be seen in the graph in Figure 4.

In the 3 years that views have been recorded, the 'Our Articles' page has had more views than the 'Other Articles' page, both individually and in total. Accounting for these views was only possible from phase 2 of the project (i.e., operation of the platform). In this case, considering 27 months from June 2021 to September 2023, there is a monthly average of 53 views for the first page and 20 for the second.

There are three reasons for this result:

(1) Most of the articles available on the 'Our Articles' page are in Portuguese (17 of the 23), the official language of the two countries responsible for the project. Naturally, the Portuguese-speaking public has a greater affinity for content published in Portuguese.
(2) The articles in English on the 'Our Articles' page (6 out of 23), which deal with themes and experiences from Brazil and Portugal, generate more interest among the public.
(3) Finally, followers of both the IRdA website and social networks become familiar with the authors, who are also members of the Institute, because they follow their movements on social networks and in webinars. This closeness generates trust and admiration for their work.

Lee *et al.* (2020) studied the influence of social ties on content engagement on social networks and found that this proximity to the general public provides admiration for the team, trust in the content, and engagement in communications.

In direct educational actions, one way of facilitating the general understanding of concepts is the LS, as already described. Similarly, a way of facilitating the understanding of scientific data in indirect educational actions is Data Production. In this case, highly relevant data are extracted from technical–scientific publications and are made available to the public by the IRdA in a summarized form.
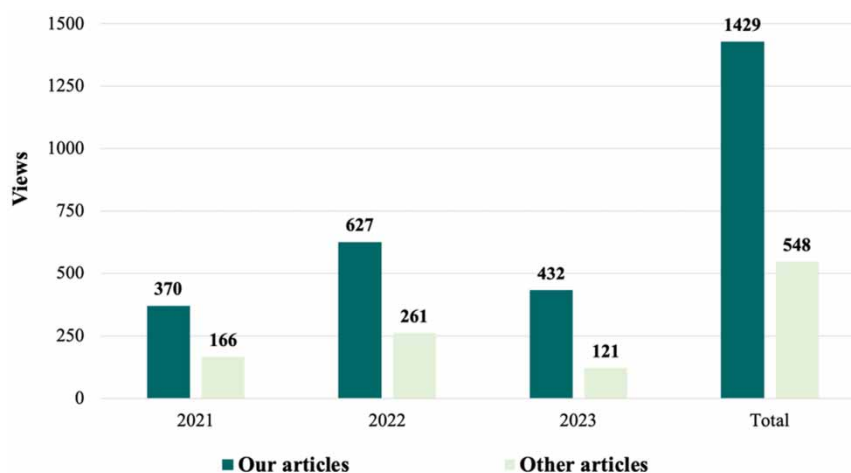

Figure 4 | Number of views of the 'Our Articles' and 'Other Articles' pages on the IRdA website.

The results relating to the three main themes of Data Production were as follows:

(i) *General regulations on water reuse:* As is discussed above, the topic of regulations is widely visited both on social networks and on the IRdA website. For this subject, 13 posts were made on LinkedIn and three on Instagram, which together achieved 910 likes and 97 shares.

(ii) *A schematic map with data on water reuse rates in various countries around the world*: As well as being of great interest to the public, the schematic map developed by the IRdA has already been cited in at least two scientific papers known to the authors (Carvalho *et al.* 2023; Pinto 2023) and an institutional technical report (CEBDS 2022). Considering the general subject of water reuse potential and case studies around the world, there were four posts on LinkedIn, with a total of 140 likes and six shares.

(iii) *Linking the SDGs to ESG and water reuse*: To link the SDGs to water reuse, the IRdA built a concept of the cross-cutting approach to water reuse in all the SDGs, presented in detail on the 'Data Production' page of the website and available in a video on the YouTube channel, with 47 views. In addition, the relationship between the SDGs and ESG and water resource management was the subject of four posts on LinkedIn and Instagram, with 217 likes and 20 shares.

Figure 5 shows access to the 'Data Production' (with 608 views in total) and 'Regulatory Framework' (with 300 views) pages on the website.

In terms of regulation, Brazil does not yet have a legal framework for regulating the practice of water reuse, although some states of the federation have already anticipated this by defining legal water quality standards for the state systematization of water reuse. These states include Bahia, Ceará, São Paulo, Minas Gerais, and Rio Grande do Sul (Santos *et al.* 2022) and, more recently, the Federal District, Mato Grosso do Sul and Paraná. In Portugal, Decree-Law No. 119 has been published since 2019 and currently falls under the aspects defined by Directive EU 741/2020 (Lima *et al.* 2022). Summaries of the water quality standards of all these documents, as well as some specific characteristics of each one, are available on the 'Regulatory Framework' page of the website.

Finally, to count the monthly views and visits of the complete content available on the IRdA website, the general data shown in Figure 6, by year, can be seen. Views are superior to visits, as they can occur more than once per visitor. It should be noted that since the launch of the *reusodeagua.org* platform in June 2021, the website has been viewed 12,548 times (in the countries highlighted in Figure 6), with an average of more than 2,000 visitors per year (average between 1,341–2,649 and 2,131).

It is also important to note that the IRdA's social networks on LinkedIn and Instagram together have 3,717 organic followers (without sponsorship). According to Lee *et al.* (2020), the involvement of social media followers is gained from the relevance of the topic to their personal and/or professional lives. Also, according to the authors, the relationship with the topic addressed generates greater participation and can culminate in favorable attitudes and behaviors related to environmental issues.
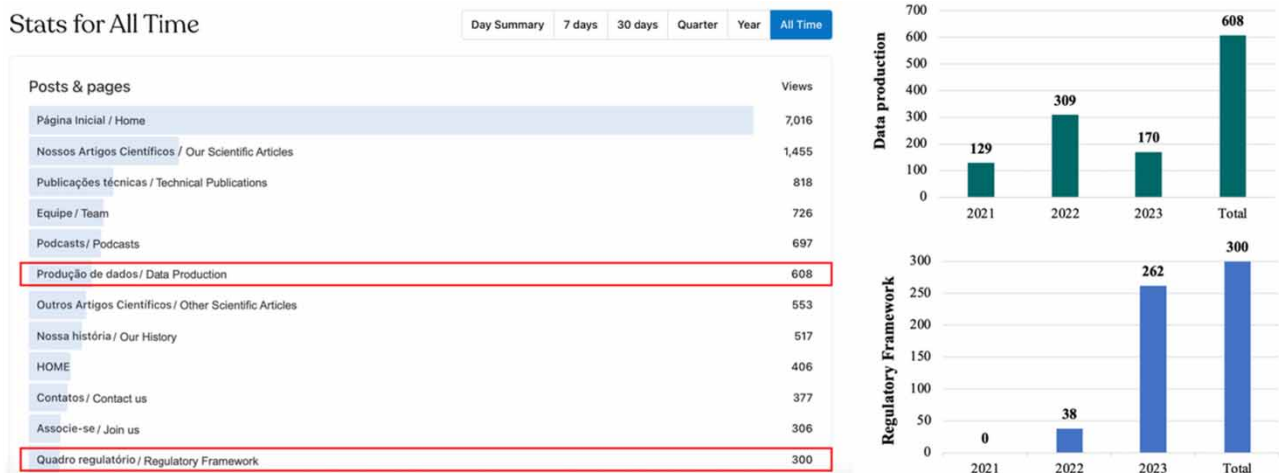

Figure 5 | Access to the 'Data Production' and 'Regulatory Framework' pages of the website.
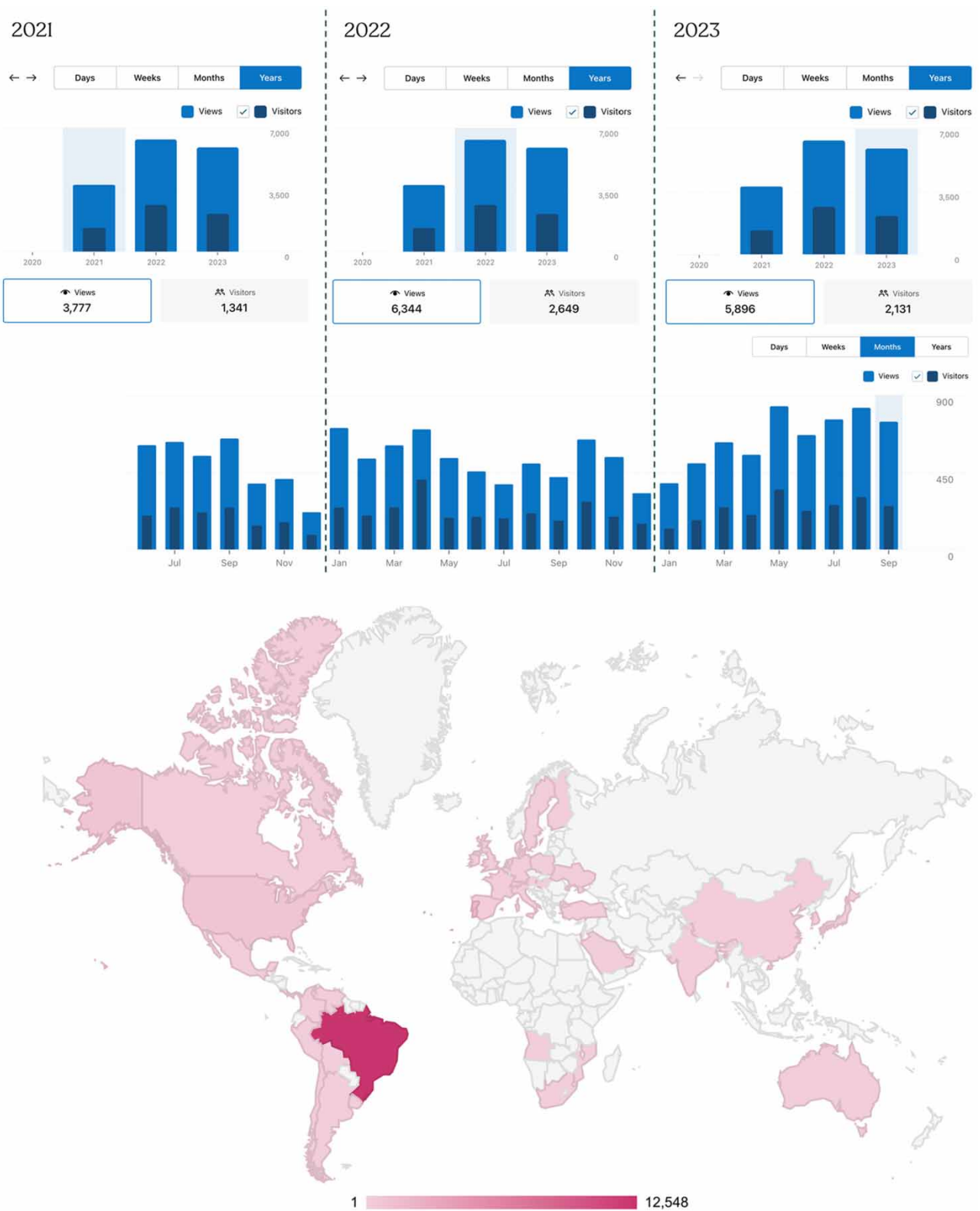
Figure 6 | Views and visitors to *reusodeagua.org*.

Direct and indirect educational actions are imagined, designed, conducted, and made available as general content on the IRdA website. All the material is produced by a technical–scientific team to promote the construction of collective knowledge. All the actors involved, in different spheres such as researchers, technicians, and society, teach and learn via the teaching–learning process. Researchers and technicians take part in webinar debates that generate content that is easier for society to assimilate. The scientific knowledge present in the technical–scientific repository, which is more difficult to understand by the society and even by technicians in the field, forms the basis of the LS and Data Production to guide the construction of this knowledge and more assertive decisions. In addition, the Mentoring Program has an inclusive character, in that more experienced technicians and researchers teach and the less experienced participants have the opportunity to assimilate in an active and participatory way.

3.3. Limitations and lessons learned

In the disruptive study conducted by Rosenberg Goldstein *et al.* (2024), which integrates psychology in evaluating the effectiveness of education on water reuse, survey participants reported having obtained information about water reuse mainly from the Internet (77%) and preferred to receive additional information mainly by watching online videos (73%). The authors also concluded that educational videos about water reuse can change the perception about this subject. Thus, the conclusions of Rosenberg Goldstein *et al.* (2024) are in line with the experience that IRdA has emerged as an effective platform for transmitting knowledge on the topic as demonstrated above.

To clarify and contribute to the development of new research and new educational approaches on water reuse, the following learnings are shared:

- Our study clearly showed greater public receptivity to the specific topic of water reuse and less interest in the scientific approach. Indeed, many authors (Angelakis *et al.* 2018; Mukherjee & Jensen 2020; Santos *et al.* 2022) have highlighted the need for adequate regulation for practical advances in water reuse in the world. In this sense, the general public demonstrates the need for more training on the topic. However, the scientific approach can be difficult to assimilate. This is more of a challenge in developing countries (Zarei *et al.* 2020), as is the case in Brazil, where our largest audience resides.
- Although the study highlighted greater receptivity to the topic 'regulation' and less to the 'scientific approach', this trend was not able to be affirmed in a general way. This statement can only be made in relation to our audience. In this sense, consideration should be given to undertaking this type of study to identify the most receptive themes in other communities with similar educational experiences, on different subjects, and in other regions.
- The scientific approach brings little engagement, considering the varied experience of the (nonscientific) public. It can frustrate those who produce this type of content. Even so, this approach must be adopted in the educational process. It is necessary to instill in the society the reliability of scientific data to achieve the desired advances and especially when it comes to trust to minimize the impact of rejection (Mukherjee & Jensen 2020). This approach must use clear and comparative language with aspects linked to everyday life.
- As highlighted by Rosenberg Goldstein *et al.* (2024), more modern educational processes, preferably ones that make use of videos, have greater reach. In this sense, IRdA is committed to transmitting knowledge through different video formats (webinars and learning series), with active and passive participation, to foster public interest.
- As highlighted by Water Europe (2020), to build a 'water smart society', it is necessary to produce, manage, and share information with a strong scientific basis and in a way which is modern, intuitive, inclusive, attractive, and easily accessible. Investing in free content can be a way of ensuring the inclusion of different members of society and, consequently, achieve active participation in this construction.
- Finally, social networks have contributed greatly to the construction of specific knowledge, such as water reuse. Furthermore, the proximity of the public to the content producers generates confidence in the results. Digital content production, management, and sharing platforms must invest in high-quality material, both visual and technical–scientific, to gain the trust of their audience.

4. CONCLUSION

Science is fundamental to the development of society. However, in some regions, such as Portugal and Brazil, the general public has little access to scientific findings on safe and responsible water reuse practices. The IRdA was created to support

the development of safe and responsible reuse practices and the dissemination of this knowledge to communities in Portugal and Brazil and elsewhere.

The findings of this study can be viewed from two perspectives: the results achieved by IRdA as a form of high efficiency environmental education tool, and the way in which its content is preferably consumed. Thus, the study contributes to other similar experiences, even considering different central subjects and other regions. The different IRdA educational actions reached a varied audience in terms of regionality and interests. While 'water reuse' is an extremely specific subject, it was concluded that it is a topic of interest in many countries around the world based on visitation to IRdA notwithstanding Portuguese is the platform's official language.

The dissemination of freely accessible content, available on the Internet, has undoubtedly proven to be an efficient and inclusive tool in active and passive educational processes, in which the public can participate directly or indirectly. It is necessary to evolve toward more attractive and inclusive educational processes, prioritizing access to digital format, in accessible language, through well-constructed videos and debates that attract public interest.

Clearly, regulation is a key issue for the public in relation to water reuse, just as the scientific approach has not proven engaging to nonscientific audience. Regulation is the necessary basis for consolidating the practice, although its approach and construction are complex. Although the scientific approach is not attractive, there is an understanding that scientific knowledge is necessary to consolidate the practice. However, the actors involved are more interested in the outcomes than in the construction of scientific research.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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