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Citizen Science from the Perspective of Higher Education Professors

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Abstract: Citizen science (CS) has the potential to be a crucial tool to effectively address positive contributions in the global context of the challenges of change in our societies and environment. Recent research highlights the growth of CS in formal education, but little is known about scientists' perceptions. This study investigated the perception of 170 faculty members from 32 Brazilian federal universities regarding public engagement across different stages of CS. We conducted a cross-sectional, descriptive study using a semi-structured questionnaire distributed via Google Forms and composed of 40 open and closed questions covering the sociodemographic, professional, and conceptual aspects of CS. The data were analyzed using descriptive statistics in Microsoft Excel®, Likert-scale responses were processed in R (version 4.1.4), and qualitative perceptions were synthesized through a word cloud analysis. The results show that most participants were women, with significant representation from the humanities. CS is widely perceived by scientists as positive and educational, despite concerns about methodological and practical limitations. Future perspectives emphasize the importance of the adoption of standardized protocols and fostering collaborative projects, particularly involving quilombola and Indigenous communities. The recognition of volunteer contributions—through acknowledgements, nominal mentions, and co-authorship—is valued, as are training programs and data validation by professional scientists, which are strongly recommended. Although many faculty members believed that CS democratizes access to science, active participation among this group remains limited. This study concludes that although faculty shows a favorable attitude toward CS, practical challenges hinder broader participation. Future efforts should focus on fostering faculty engagement, implementing robust training and validation procedures, and developing inclusive, community-based research models.

Keywords: participatory science; perception; scientists; public university; Brazil

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1. Introduction

Universities' primary mission is to co-create and share knowledge. Scholars must also contribute to educating all surrounding communities, especially in the current global context, with geopolitical and climate change threats (Lindemann et al., 2022; Nissen et al., 2020). When new technologies are readily available, they must be channeled for beneficial purposes (Kobori et al., 2016). Thus, citizen science has the potential to effectively contribute to the ultimate mission of universities by simply representing the value of scientific production and the potential benefits of these research activities for each individual in society and for the planet as a whole (Carayannis & Morawska-Jancelewicz, 2022; Trencher et al., 2014). Public engagement with science, especially through citizen science (CS), has grown significantly in recent decades, being recognized as a promising way to expand knowledge production, democratize science, and bring scientists closer to society (Bonney et al., 2016; Haklay et al., 2021; Shirk et al., 2012). Although CS is not a recent practice, its adoption in scientific projects has intensified thanks to technological advances, such as the use of smartphones, digital platforms, and georeferencing tools (Kullenberg & Kasperowski, 2016; Jordan et al., 2012), as well as institutional recognition of its potential to generate relevant data and foster public engagement (Robinson et al., 2024).

The scientific literature has extensively documented the successful use of citizen science in a variety of fields (e.g., biology, ecology, astronomy, public health, and social sciences), particularly as technological advances have facilitated public engagement in projects of varying scales and complexities, notably projects such as eBird, Reef Life Survey, Redmap, Zooniverse, and the Secchi Disk Project (Edgar et al., 2020; Franzoni & Sauermann, 2014; Pecl et al., 2019). These programs demonstrate that, when well structured, citizen science projects can present methodological rigor comparable to that of initiatives led exclusively by scientists, even though volunteers are mostly involved in data collection (Kosmala et al., 2016; Wiggins et al., 2011).

Despite the advances in CS, resistance still persists in the scientific community, especially regarding the reliability of data generated by non-specialized citizens. This resistance is intensified by the diversity of participation models, which range from contributory initiatives to co-created projects, each with different levels of engagement and shared responsibilities. Such resistance is often associated with the perception that participants lack technical and scientific training, which could compromise the quality and validity of the results (Resnik et al., 2015; Strasser et al., 2019). However, studies show that data quality can be ensured through standardized protocols, cross-validation, and adequate training (Haklay et al., 2021; Newman et al., 2017).

Although CS is seen globally as an opportunity to strengthen the link between science and society, in Brazil, it still faces specific challenges, such as the low participation of traditional communities, limited technological infrastructure, and the centralization of knowledge in higher education institutions (Da Silva et al., 2025b; Guerrero-Moreno et al., 2024; Levis et al., 2024). These obstacles, in turn, are compounded by the diversity of existing participation models in CS, which range from contributory initiatives (focused on data collection) to co-created projects (with joint planning and analysis), presenting different levels of engagement and shared responsibility between scientists and citizens (Bonney et al., 2016; Shirk et al., 2012). Even so, initiatives such as the participatory monitoring of ICMBio (Chico Mendes Institute for Biodiversity Conservation) demonstrate that it is possible to integrate traditional and scientific knowledge in collaborative actions (Da Silva et al., 2025b; Guerrero-Moreno et al., 2024).

These challenges make the role of higher education institutions even more relevant, especially federal universities, where professors have a strategic position to foster or, in some cases, hinder the advancement of citizen science. As opinion makers, decision makers, and knowledge producers, their perceptions, experiences, and motivations are fundamental to understanding the possible paths for the consolidation of CS as a legitimate practice in academic research (Besley & Nisbet, 2013; Collins et al., 2022). Although many recognize the benefits of public participation in science, studies indicate that effective adherence is still limited by a lack of knowledge, time, and institutional incentives, as well as a fear of acceptance by the scientific community (Balázs et al., 2021; T. B. Phillips et al., 2019; Riesch & Potter, 2014).

In this context, this study aimed to analyze the perception of professors from Brazilian federal universities about public involvement in different stages of the citizen science process, including the planning, collection, analysis and dissemination of data. The research hypothesis is that professors from Brazilian federal universities have a positive perception of citizen science, considering it useful for scientific development and the social participation of citizens. This is based on the premise that the interaction between scientists and citizens, especially in collaborative processes, has the potential to transform traditional perceptions about the roles of each in the production of knowledge. This coexistence can broaden researchers' understanding of local knowledge, social demands, and the importance of including multiple actors in scientific work, in addition to reinforcing confidence in the quality of data generated by non-specialists. Studies show that when experiencing practical experiences of public engagement, scientists tend to review previous conceptions, becoming more open to cooperation, more sensitive to social issues, and more confident in the ability of citizens to contribute significantly to science (Bonney et al., 2016; Burchell, 2015; Llorente et al., 2019; Newman et al., 2017).

2. Materials and Methods

2.1. Study Objectives and Research Hypothesis

This study aimed to analyze how professors from Brazilian federal universities perceive public involvement in different stages of the citizen science process, including planning, data collection, analysis, and dissemination. The underlying hypothesis is that these professors hold a generally positive view of citizen science, recognizing it as a valuable tool for both scientific advancement and public engagement. Understanding these perceptions is essential to identify opportunities and challenges for strengthening collaborative practices between scientists and society.

2.2. Data Collection Procedure

This study received approval from the Research Ethics Committee of the Universidade Federal do Oeste do Pará (authorization number 5.495.380) prior to data collection. Invitations to participate were sent to all 69 Brazilian federal universities, with 32 institutions consenting to participate (see Supplementary Materials, Figure S1).

Data collection occurred between October and December 2023 using a semi-structured questionnaire (see Supplementary Materials, Questionnaire S2) administered online through Google Forms (Da Costa Andres et al., 2020). This method consisted of asking open (qualitative) and closed (quantitative) questions in both physical and online formats in order to identify the perceptions of a specific audience, allowing respondents to freely develop their answers in certain sections (Ranganathan & Caduff, 2023).

The questionnaire was developed specifically for this study, comprising 40 open and closed questions organized into four sections: (1) Informed Consent Form: an essential document to ensure that participants understand and voluntarily consent to the use of the information provided for academic and scientific purposes; (2) Sociodemographic and Socioprofessional Information: includes information on sex, age group, color/ethnicity, qualification, and area of activity; (3) General Aspects of Citizen Science: includes verifying professors' understanding of the concept of citizen science and citizen scientists, as well as the importance and limitations of the practice; (4) Specific Aspects of Citizen Science: addresses the level of engagement; methods, tools and participatory attitudes used; types of citizen scientists; and data collection involved in the activities, in addition to data validation by professionals. Before deployment, a pre-test was conducted with a group of professors to ensure clarity, identify potential flaws, estimate completion time, and assess participant interest (Waldis et al., 2019).

A convenience sampling approach was employed, targeting tenured professors from 32 Brazilian federal universities—out of the 69 that fell under this administrative category—who were aged 18 or older and consented to participate. This non-probabilistic method involved selecting participants who were easily accessible and willing to participate, with agreement to participate being the sole criterion (Chandler & Shapiro, 2016; Jouaville et al., 2021; Shamsudin et al., 2024). This is considered a fast, practical, and cost-effective strategy commonly used in research. The inclusion criteria were the following: (i) being a tenured professor at one of the 32 participating institutions; (ii) being 18 years of age or older; and (iii) agreeing to the Informed Consent Form (ICF) (see Figure S1). Professors who did not respond within three months were excluded. A total of 170 professors completed the questionnaire, representing diverse academic disciplines such as the humanities, biological and health sciences, exact and earth sciences, applied social sciences, engineering, agricultural sciences, environmental sciences, linguistics, literature, arts, interdisciplinary studies, and computing. Most respondents held doctoral degrees and were active in higher education. Further sociodemographic and socioprofessional details of the sample are presented in Section 3.1.

2.3. Data Analysis

The data were analyzed using Microsoft Excel® 2016 software, where a database was initially created with the information collected. Then, a descriptive statistical analysis was performed by calculating the relative frequencies of the responses provided, and the results were presented through graphs and tables for a subsequent discussion of the results. Excel is a widely used tool for data analysis, being very efficient and versatile in controlling and organizing information. In addition, it offers resources for creating graphs and tables that facilitate data interpretation (Akpan, 2024; Bandara et al., 2015).

A keyword cloud analysis was performed on the respondents' perception of specific concepts of citizen science using the online tool WordArt (https://wordart.com/, accessed on 20 August 2024). The cloud was generated from visual representations of text, highlighting the most mentioned words. A total of 20 words were considered.

The responses presented on the Likert scale were analyzed in the R program, version 4.1.4, and the results were presented in graphs that indicate the percentage of agreement of the respondents for each question. This tool is widely used by researchers to assess perceptions and attitudes by indicating the degree of agreement or disagreement in relation to each question using five categories of responses that range from "totally disagree" to "totally agree" (Asaie, 2024; Malhotra, 2019).

A correspondence analysis (CA) and canonical correspondence analysis (CCA) were performed for more robust statistics (Greenacre, 2007). Initially, CAs was performed separately for the citizen science matrix and the citizen scientist matrix. These analyses aimed to explore the internal structures of the responses of each group, identifying patterns of association between the response categories. The groups analyzed were the areas of activity of the researchers and the responses given by these scientists, represented as follows: A1—Yes; A2—No; and A3—I do not know how to answer. Subsequently, two CCAs were conducted, with the aim of investigating the relationship between the response variables of the citizen science and citizen scientist matrices versus the explanatory variables of the perceptions quantified in questions Q1 to Q11 of the Likert scale, also considering the influence of the participants' area of activity. All analyses were performed in the R software (version 4.1.4) using the vegan package (Oksanen et al., 2020).

3. Results and Discussion

3.1. Sociodemographic and Socioprofessional Characteristics of the Study Participants

Of the 170 respondents, 51.18% (*n* = 87) were women and 48.82% (*n* = 83) were men. Regarding race or ethnicity, 58.82% (*n* = 100) of the participants identified themselves as white, 29.41% (*n* = 50) as brown, 7.65% (*n* = 13) as black, and less than 3% self-identified as Asian, Indigenous, or preferred not to state. Regarding educational level, 86.47% (*n* = 147) of the faculty held a doctorate as their highest academic degree, while 13.53% (*n* = 23) held a master's degree. Regarding the areas of action of the professors, the main one was human sciences (25.29%; *n* = 43), followed by biological and health sciences (15.88%; *n* = 27) (Table 1).

Table 1. Sociodemographic and socioprofessional characteristics of the professor respondents from Brazilian federal universities. N = number.

Sociodemographic Variables	Individuals		Socioprofessional Variables	Individuals	
	N	%		N	%
Sex			Degree		
Male	83	48.82	Master's Degree	23	13.53
Female	87	51.18	Doctorate	147	86.47
Total	170	100	Total	170	100
Age group (in years)			Area of expertise		
25–34	17	10.00			
35–44	81	47.64	Agricultural Sciences	12	7.06
45–54	47	27.65	Environmental Sciences	3	1.76
55–64	19	11.18	Biological Sciences	27	15.88
>65	6	3.53	Health Sciences	27	15.88
Total	170	100	Exact and Earth Sciences	17	10.00
Color/ethnicity			Human Sciences	43	25.29
Asian	3	1.76	Applied Social Sciences	14	8.24
White	100	58.82	Computing	1	0.6
Indigenous	1	0.6	Engineering	10	5.88
Black	13	7.65	Interdisciplinary	10	5.88
Mixed race	50	29.41	Linguistics, Literature, and Arts	6	3.53
I prefer not to say	3	1.76			
Total	170	100	Total	170	100

Gender data reflect the growing number of women holding academic and management positions in Brazilian universities (Beigel et al., 2023; Esnard & Grangeiro, 2025). This distribution also follows a national trend, where the female population represents 51.5% and the male population 48.5% (IBGE, 2022). Regarding the racial dimension, the low presence of black and Indigenous people in universities can be explained by social inequalities in access to higher education and academic careers (Arantes, 2021). These data reinforce the need for affirmative-action public policies that promote greater racial inclusion in higher education (Heringer, 2024; Zeidan et al., 2024). Furthermore, the results confirm that higher education continues to be an environment predominantly composed of self-declared white faculty, with 76.67% representation in this profile (Brito et al., 2022; Ferreira et al., 2022).

The high percentage of professors with doctorates highlights the advanced level of training of the teaching staff, aligned with the institutional policy of federal universities, which demands a highly qualified academic profile, in accordance with the requirements of higher education in Brazil (Nunes-Silva et al., 2019). According to data from the National Education Plan (PNE), the percentage of doctorates has grown in the country in recent years (Ma et al., 2023). In turn, the requirement of a doctorate for teaching at public universities contributes to the recognition of institutions, scientific production, and the quality of teaching and research in the country (Almeida & Érnica, 2016; Schwartzman & Balbachevsky, 2013). However, it is necessary to continually value professionals in higher education and basic/technical education through incentives for continuing education, better working conditions, and the reduction in regional inequalities. Only in this way, by promoting educational and technological progress in an inclusive manner, will Brazil be able to remain competitive on the international stage (Fernandes, 2024; Santos & Freitas, 2025).

Finally, the predominance of the humanities as a field of practice is linked to a strong female presence in academia, as the majority of women (54%) are concentrated in arts, humanities, and social sciences (UNESCO, 2022). This suggests that areas such as education, social sciences, and health have received significant attention both from an academic perspective and in public policymaking due to their social relevance (Bernier & Clavier, 2011; Rich, 2018). These disciplines are not only essential for interpreting and addressing complex societal challenges, but they also play a strategic role in the development of inclusive policies, the promotion of social justice, and the construction of more equitable and sustainable societies (Kohout-Diaz, 2025).

3.2. Analysis of General Characteristics of Citizen Science

3.2.1. Participants' Perceptions of Concepts and Participation in Citizen Science

The results show that 48.82% (n = 83) of professionals understood the concept of citizen science; however, 42.35% (n = 72) were unfamiliar with the term used in the research, and 9% (n = 15) did not know how to respond (Figure 1). Regarding the concept of citizen scientists, 45.29% (n = 77) of the teaching staff stated they were familiar with it; however, 40.59% (n = 69) did not understand it, and 14.12% (n = 24) did not know how to respond (Figure 1). Regarding the perception of whether citizen science is a recent concept (year 2000), the majority (44.71%; n = 76) believed this is the case. However, 32.35% (n = 55) did not know how to answer and 22.94% (n = 39) did not consider this period (Figure 1). Regarding participation in citizen science activities, a significant number of professors, 65.88% (n = 112), declared not to participate, while 23% (n = 39) were involved with the topic and 11.18% (n = 19) did not know how to answer (Figure 1).

While most respondents understood the concept of citizen science, a large percentage found it difficult to define. This may be due to the fact that the term in question has numerous approaches and encompasses diverse initiatives (Haklay et al., 2021; Kullenberg & Kasperowski, 2016). For Wiggins and Crowston (2011), for example, citizen science is a form of scientific research characterized by active public participation in the different stages of the scientific process. For other authors, it is a collaborative approach that involves not only professional scientists, who have formal academic training and carry out scientific activities in higher education institutions and public and/or private research centers, but also citizens in the construction of scientific knowledge (Bonney et al., 2016; Giardullo, 2023; Ha, 2022). Some authors also emphasize the citizen scientist as a person without formal academic or professional training who contributes significantly to scientific research (Cohn, 2008; Rudnicka et al., 2022). These individuals are trained to collect, analyze, and interpret data, and can also act as co-authors on scientific projects (Fraisl et al., 2022; O'Grady & Mangina, 2024; Riesch & Potter, 2014).

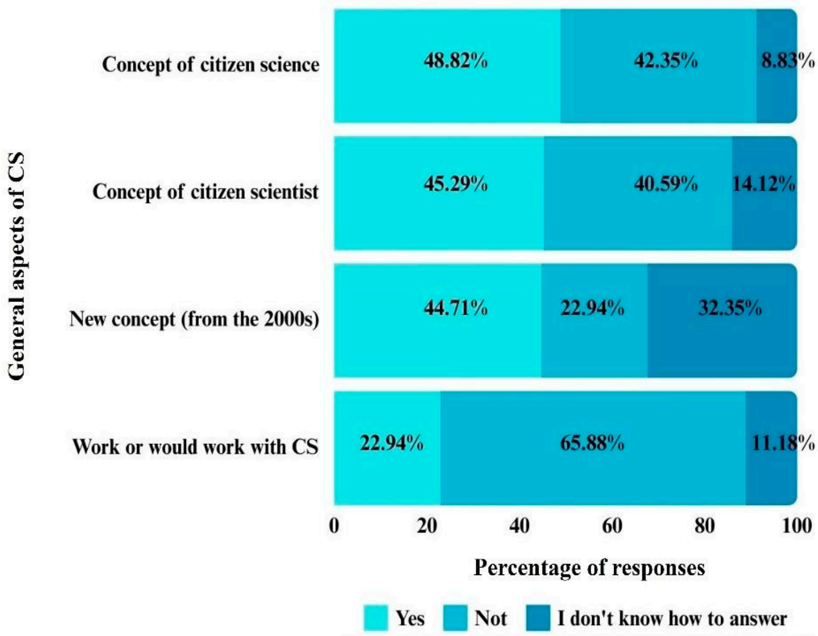

Figure 1. Professors' perception of general aspects of citizen science. CS = citizen science.

On the other hand, the majority of respondents believed that citizen science emerged recently. This may be associated with the success of many projects that used digital platforms to observe, collect, and analyze data during the year 2000, with the results subsequently published in peer-reviewed scientific journals (Davis et al., 2023; Skarlatidou et al., 2019). Added to this is the easy access to information and communication in the digital age, which has allowed science-motivated citizens to participate in scientific research in diverse areas, such as environmental monitoring, astronomy, ornithology, ecology, and genetics (Dickinson et al., 2012; Miller-Rushing et al., 2012). Currently, several platforms, online programs, and organizations facilitate interactions between scientists and citizens in scientific projects, with the aim of fostering the advancement and impact of citizen science (Liu et al., 2021; Sauermann et al., 2020). Rising global literacy and educational attainment have been significant, enabling many more people to contribute significantly to the construction of knowledge (Fraisl et al., 2022).

Finally, it can be observed that although many scientists understand the concept of citizen science, few professionals engage in or work on initiatives related to the topic. In this sense, Latin American scientists have demonstrated a positive attitude toward citizen science (CS), although the focus has frequently been on data collection and the communication of research results to the public (Nicholls et al., 2020; Viana et al., 2020). This low participation rate can be explained by several factors, such as the absence of citizen science practices in scientists' professional routine, the scarcity of financial resources to maintain existing projects or start new ones (Riesch & Potter, 2014), communication barriers between scientists and the general public (Paul et al., 2020), and the lack of institutional recognition of outreach and dissemination activities (Sorensen et al., 2019). Added to this is the lack of training in citizen science, as well as skepticism regarding the quality of data collected by non-professional collaborators (Queiroz-Souza et al., 2023).

3.2.2. Participants' Perceptions of Citizen Science and Citizen Scientists

The concepts of citizen science and citizen scientists are represented by the prominent terms in the word clouds below (Figure 2a,b). When describing citizen science, the most prominent words were extension projects (n = 15), participatory research (n = 14), open science (n = 12), action research (n = 10), and participatory science (n = 7) (Figure 2a).

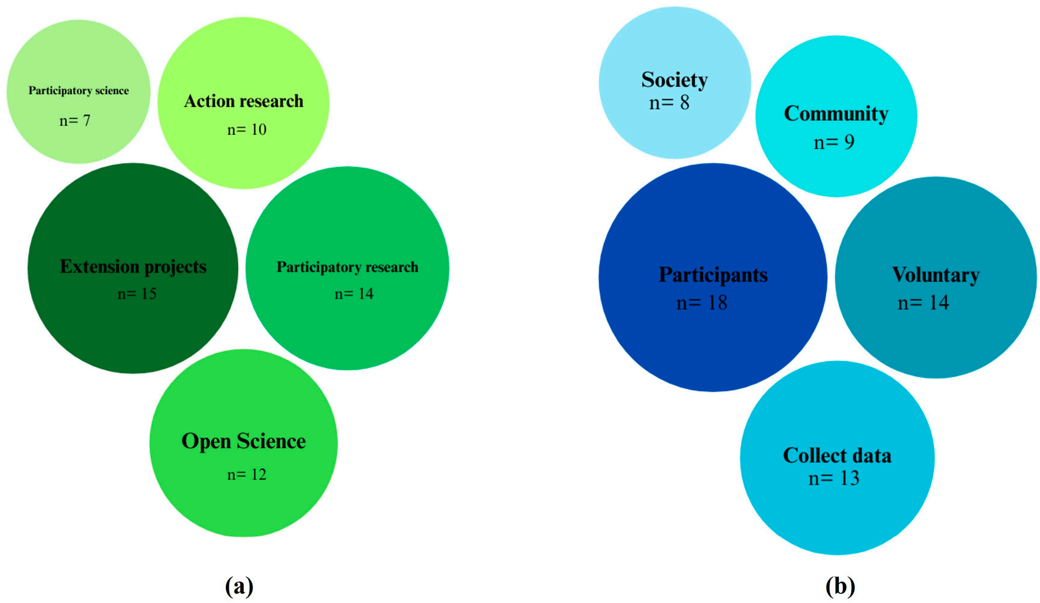

Figure 2. Word cloud of the terms most frequently mentioned by respondents regarding the concepts of (**a**) citizen science and (**b**) citizen scientists. The size of the circles indicates the frequency with which the terms were mentioned. N = number.

The emphasis on the terms "extension projects" and "participatory research" indicates that in Brazilian federal institutions, citizen science is considered a way to strengthen the relationship between the university and society (Sá et al., 2022; Skarzauskiene & Mačiulienė, 2021). University extension is seen as conducive to citizen science, as it historically aims to promote dialogue between higher education institutions and communities (Fitzgerald et al., 2020; Scholz, 2017). Furthermore, the emphasis on participatory methodologies, such as participatory research and action research, reveals a tendency towards direct involvement in the scientific process, which reinforces the inclusive and collaborative nature of citizen science (Kimura & Kinchy, 2016; Vasiliades et al., 2021).

The term "open science" suggests that educators are aware of global changes in the openness of scientific knowledge, which seeks to make science easily understandable to the public (Elliott & Resnik, 2019; Lakomý et al., 2019). In this context, citizen science benefits from open science practices, as citizens can access and contribute to data and discoveries more broadly (Arza & Fressoli, 2017; Pardo Martínez & Poveda, 2018).

For the concept of the citizen scientist, the most frequently mentioned terms were participants (n = 18), volunteer (n = 14), collect data (n = 13), community (n = 9), and society (n = 8) (Figure 2b). Professors at Brazilian federal universities associate citizens with instructed collaborators, whose participation is organized and directed by professionals, with a predominance of the terms "participants" and "volunteers" (Eitzel et al., 2017; Haklay et al., 2021). This suggests the view that citizens play a fundamental role in expanding scientific research, although they act under the supervision of scientists (A. Land-Zandstra et al., 2021; Riesch & Potter, 2014). On the other hand, the terms "community" and "society" indicate a more horizontal and collaborative view of citizen science, where the citizen scientist is recognized as a social actor, capable of contributing directly and in a relevant way to solving real problems and to the production of knowledge (Barbato et al., 2024; Butkevičienė et al., 2021).

The term "collect data" was mentioned frequently, suggesting that, although citizens are recognized for their contribution to data collection, there are still limitations regarding their participation in the stages of the co-creation, analysis, and dissemination of scientific results (Bonney et al., 2016; Strasser et al., 2019). Thus, it is necessary to develop a more integrated and participatory vision of citizen science, involving citizens in all phases of the scientific process (Hecker et al., 2018) in Brazilian universities.

3.2.3. Perceptions of the Importance of Citizen Science

The results show that 76% of respondents (Q1) considered citizen science important for the development of scientific research. Furthermore, 75% (Q2) believed this practice facilitates public participation in the scientific process, and 69% (Q3) expressed confidence in data collected by citizen scientists. Likewise, 85% of faculty (Q4) stated that data generated by volunteers is important for research, and 82% (Q5) agreed that citizen science facilitates data collection, especially in large-scale studies. Regarding access to results, 71% of respondents (Q6) believed that citizen science improves communication between scientific results and society (Figure 3). Furthermore, 73% (Q7) consider it an effective tool for scientific outreach, enabling a more direct connection between scientists and citizens (Figure 3).

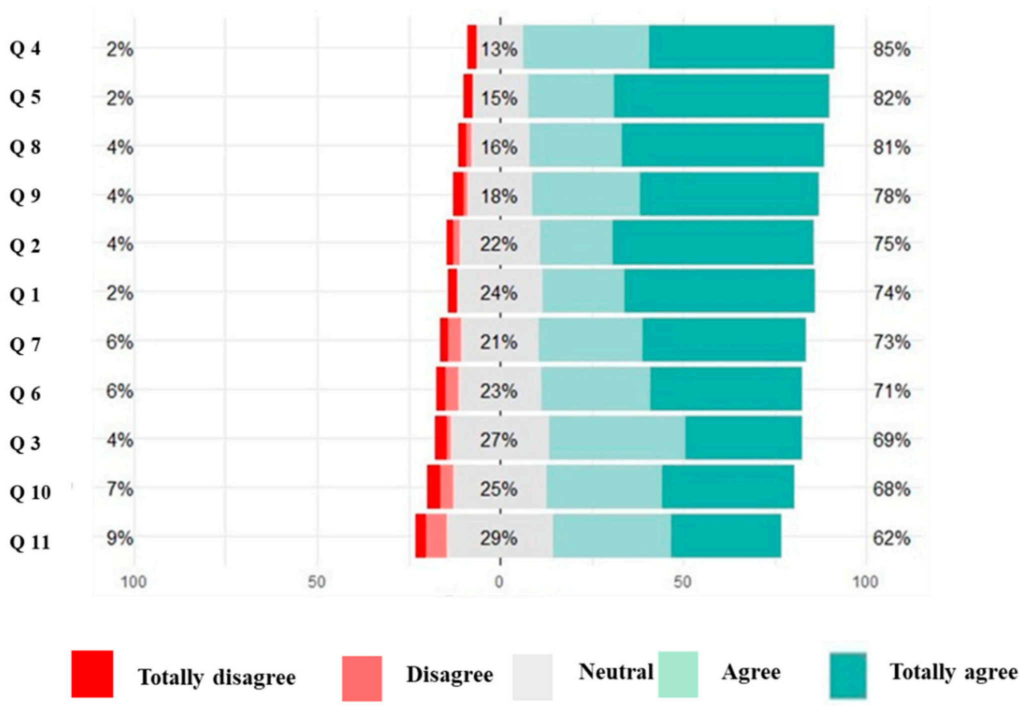

Figure 3. Analysis of responses to the Likert scale. In the left column, it is possible to observe the ordered list of the questions that the participants judged. In the right column, the levels of agreement are shown as percentages. Q = Question. Q1—How important is citizen science (CS) for scientific research? Q2—Does CS involve the public in the scientific research process? Q3—Are the data obtained by volunteers (citizen scientists) reliable? Q4—Can the data obtained by citizen scientists be useful for scientific research? Q5—Do CS initiatives facilitate and expand the collection of scientific data? Q6—Do CS initiatives allow society to have access to the results of scientific research? Q7—Are CS initiatives a tool for scientific dissemination? Q8—Do CS initiatives contribute to raising awareness among citizens about the importance of science in solving society's problems? Q9—Do CS initiatives function as a space for dialogue in which society presents demands to scientists to transform into an object of study? Q10—Do data collected by citizen scientists provide an economical solution for exploring research questions on a large scale? Q11—Do you believe that CS has limitations?

On the other hand, 81% of participants (Q8) believed that citizen science contributes to increasing public awareness of the importance of science in solving social problems, and they highlighted its educational potential. In addition, 78% (Q9) believed that this practice can act as a space for dialogue between science and society. A total of 68% (Q10) also recognized that citizen science offers a cost-effective and viable solution for addressing scientific questions. However, 62% of participants (Q11) acknowledged that this practice has limitations.

The results reflect a widespread acceptance of citizen science among Brazilian university faculty, who recognize it as an effective practice for expanding the scope of scientific research. This position is supported by the literature, which highlights how citizen participation enables the collection of large volumes of data, particularly useful in topics such as climate change (Pecl et al., 2019), species conservation (Bosso et al., 2024), environmental monitoring (Maillard et al., 2024), and water quality (Capdevila et al., 2020; Ramírez et al., 2023).

There is also a positive perception of volunteer-generated data. This is consistent with studies highlighting how citizen science can overcome logistical and economic limitations in large-scale research, emphasizing the role of citizen scientists in providing data (Dickinson et al., 2010; Fraisl et al., 2022). This is important because it recognizes the role of citizens in generating knowledge across large areas and over long periods of time, which would be difficult to achieve strictly with traditional scientific resources (Sullivan et al., 2014; Golumbic et al., 2017).

In social terms, the results underscore the democratizing role of citizen science. Faculty value its ability to bring science closer to society, improve scientific communication, and enable the participation of people without specialized training in knowledge construction (Bonney et al., 2016; Rautela, 2024). This reinforces the idea that anyone, regardless of their institutional affiliation, can actively engage in science and make a meaningful contribution.

Additionally, the educational and social awareness-raising potential of citizen science was also highlighted. This is associated with the fact that by allowing direct participation by volunteers in the scientific process, this practice promotes a better understanding of scientific methods and strengthens the role of citizens as active agents in solving local and global problems (Eitzel et al., 2017; Riesch & Potter, 2014). Thus, it constitutes a fertile field for dialogue between science and society, as well as for the training of future scientists, as proposed by Bonney et al. (2016) and Shirk et al. (2012).

Finally, participants expressed limitations related to CS. One of the main limitations revolved around the quality of the data generated by citizens without formal scientific training (Follett & Strezov, 2015; Kosmala et al., 2016), which could affect the reliability of the results. They also highlighted practical limitations, such as the availability of time, resources, and technical knowledge among participants (Haklay, 2012; Walker et al., 2021). Another limitation revolved around some areas of knowledge, which require complex methodologies that cannot always be easily communicated to the general public (Buytaert et al., 2014). In some cases, participation may be restricted by the need for specialized training or by a lack of access to specialized scientific tools (Spasiano et al., 2021; Viana et al., 2020). In this context, it is essential to establish appropriate training protocols, along with strategies to ensure data quality and ongoing support from specialists. Only then will it be possible to consolidate truly collaborative, inclusive, robust, and contextualized citizen science (Hecker et al., 2018).

3.2.4. Relationships Between Perceptions of Citizen Science Concepts, Citizen Scientists, and the Perceived Importance of Citizen Science

The correspondence analysis (CA) (Figure 4), conducted between professors' areas of expertise and the words mentioned to define the concept of citizen science, revealed that professionals from the fields of human sciences and exact sciences reported an understanding of citizen science, particularly linking it to the term extension project (W1). Professors from the biological sciences area most frequently associated open science (W3) with the concept of citizen science. The expression participatory science (W5) was more often cited by educators from the interdisciplinary, educational, and agricultural sciences fields. It was also observed that the terms participatory research (W2) and action research (W4) showed a marked absence of association with citizen science among professors from the biological, exact, and human sciences, as well as from the interdisciplinary, educational, and agricultural sciences, respectively (Figure 4).

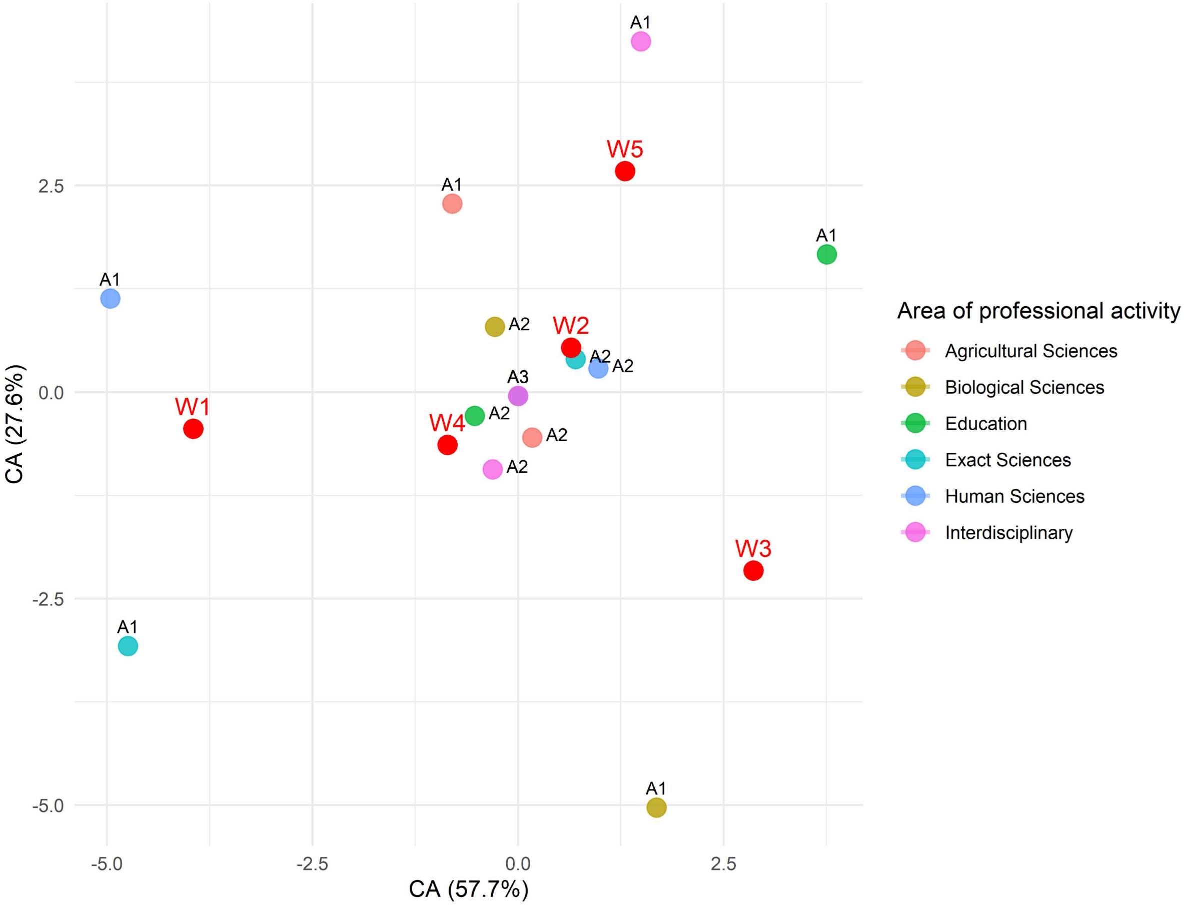

Figure 4. Correspondence analysis (CA) showing the relationship between professors' areas of expertise (colored circles) and the words mentioned as concepts of citizen science (darker red circles). W1—extension project; W2—participatory research; W3—open science; W4—action research; W5—participatory science. A1—yes; A2—no; A3—I do not know how to answer.

The correspondence analysis (CA) (Figure 5) conducted between professors' areas of expertise and the words mentioned to define the concept of a citizen scientist revealed that the expression participants (W1) was predominantly cited as the concept of a citizen scientist in the educational, agricultural sciences, and human sciences fields. The term volunteers (W2) was more strongly associated with professors from the biological and exact sciences. The word society (W5) was most frequently related to the concept of a citizen scientist by professors from the interdisciplinary field. Conversely, the expressions data collection (W3) and community (W4) were less recognized as central concepts of a citizen scientist across all the areas of expertise analyzed (Figure 5).

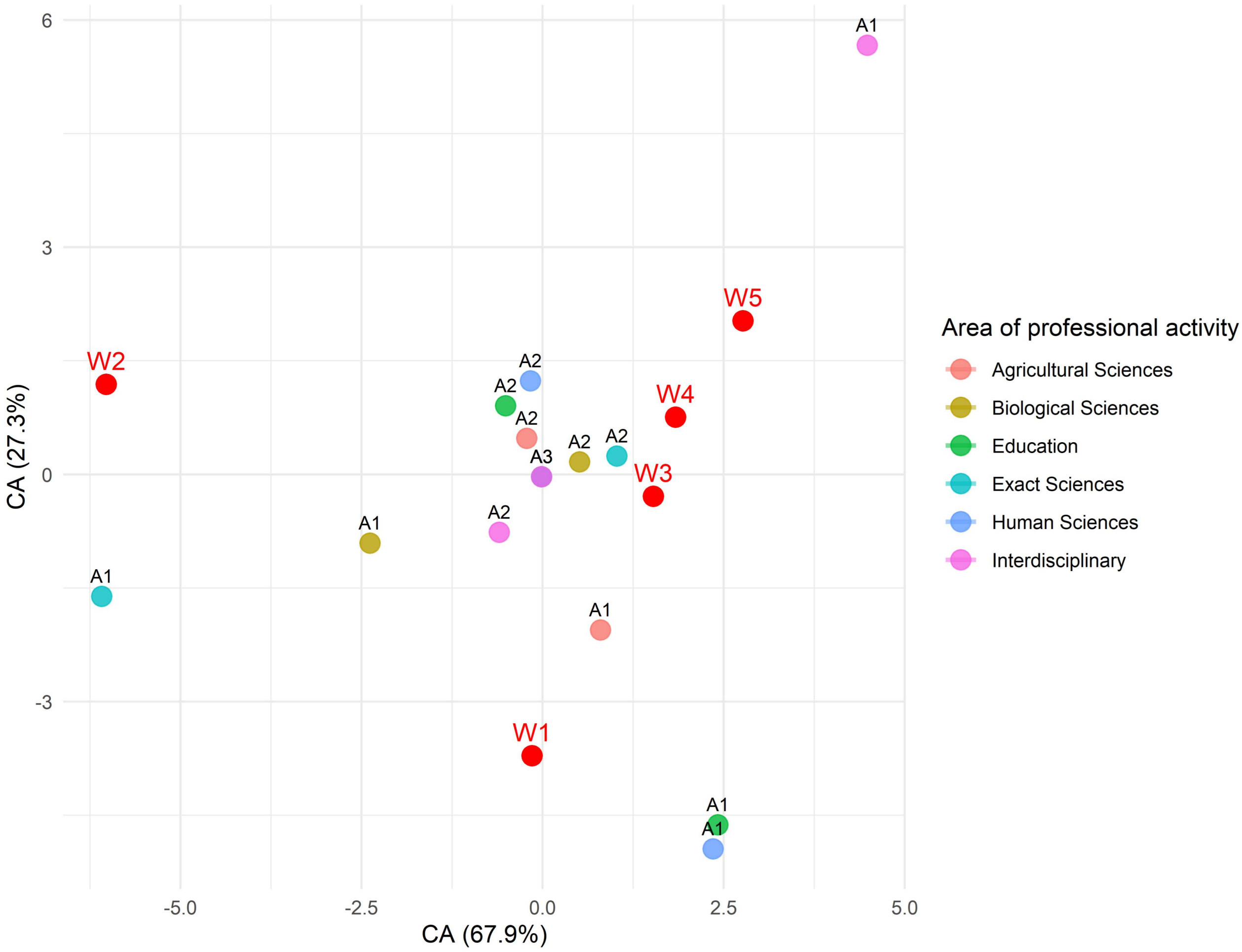

Figure 5. Correspondence analysis (CA) showing the relationship between professors' areas of expertise (colored circles) and the words mentioned as concepts of citizen scientist (darker red circles). W1—participants; W2—volunteers; W3—data collection; W4—community; W5—society. A1—yes; A2—no; A3—I do not know how to answer.

The canonical correspondence analysis (CCA) (Figure 6), conducted between the most frequently cited words used by professors to define citizen science (Figure 2a) and the questions related to its perceived importance and limitations (Figure 3), revealed relevant interpretative patterns. A strong correlation was observed between the term extension project (W1) and the statements that data obtained by citizen scientists are useful for scientific research (Q4) and that citizen science presents certain limitations (Q11). The expression participatory research (W2) showed a positive association with the perception of citizen science as important for advancing scientific research (Q1). Meanwhile, the concept of open science (W3) was strongly correlated with the view that citizen science initiatives provide society with access to the results of scientific research (Q6). Finally, the terms action research (W4) and participatory science (W5) were associated both with the idea that citizen science initiatives serve as platforms for dialogue between society and researchers (Q9) and with the perception that data collected by citizen scientists offer a cost-effective solution for conducting large-scale research (Q10) (Figure 6).

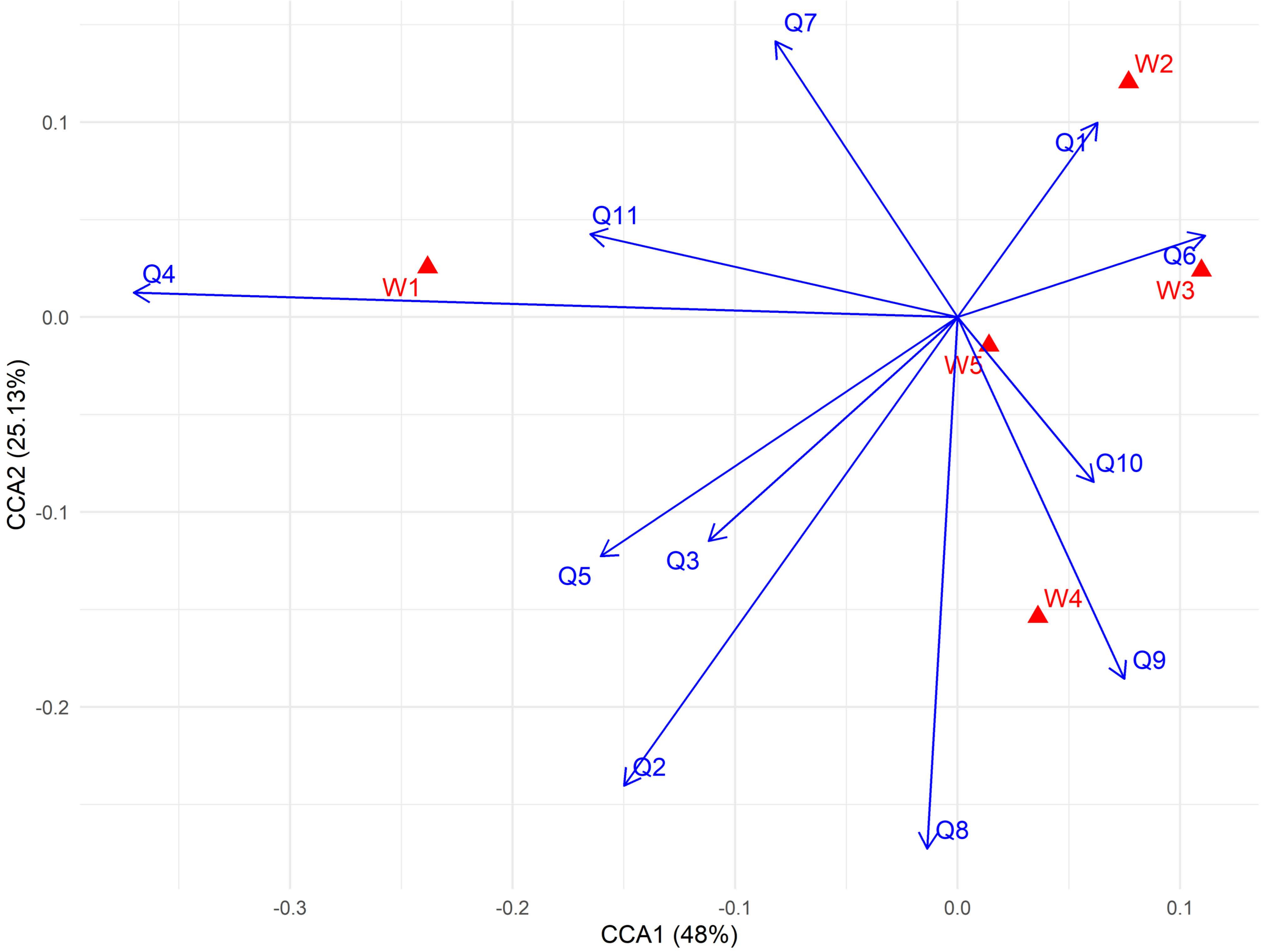

Figure 6. Canonical correspondence analysis (CCA) showing the relationship between the perception of the concept of citizen science and issues related to the importance and limitations of citizen science. W = Words (represented by the red triangle). W1—extension project; W2—participatory research; W3—open science; W4—action research; W5—participatory science. Q = Question. Q1—How important is citizen science (CS) for scientific research? Q2—Does CS involve the public in the scientific research process? Q3—Are the data obtained by volunteers (citizen scientists) reliable? Q4—Can the data obtained by citizen scientists be useful for scientific research? Q5—Do CS initiatives facilitate and expand the collection of scientific data? Q6—Do CS initiatives allow society to have access to the results of scientific research? Q7—Are CS initiatives a tool for scientific dissemination? Q8—Do CS initiatives contribute to raising awareness among citizens about the importance of science in solving society's problems? Q9—Do CS initiatives function as a space for dialogue in which society presents demands to scientists to transform into an object of study? Q10—Do data collected by citizen scientists provide an economical solution for exploring research questions on a large scale? Q11—Do you believe that CS has limitations?

Finally, the canonical correspondence analysis (CCA) (Figure 7), conducted between the words most frequently mentioned by professors regarding the concept of a citizen scientist (Figure 2b) and the questions related to the perceived importance and limitations of citizen science (Figure 3), also revealed significant correlations. The term participants (W1) showed a negative association with the perception that data collected by citizen scientists provide a cost-effective solution for large-scale research (Q10). The word volunteers (W2) was strongly associated with the perception of public engagement in the scientific research process (Q2), the reliability of the data collected by volunteers (Q3), and the public's access to the results of scientific research (Q6). The expression data collection (W3) demonstrated an inverse association both with the perceived usefulness of the data obtained by citizen scientists for scientific research (Q4) and with the potential of citizen science to facilitate and expand scientific data collection (Q5). Conversely, the term community (W4) was positively correlated with the view of citizen science as a tool for scientific dissemination (Q7) and for raising public awareness about the role of science (Q8). Finally, the word society (W5) was directly associated with perceptions of the limitations inherent in citizen science practices (Q11) (Figure 7).

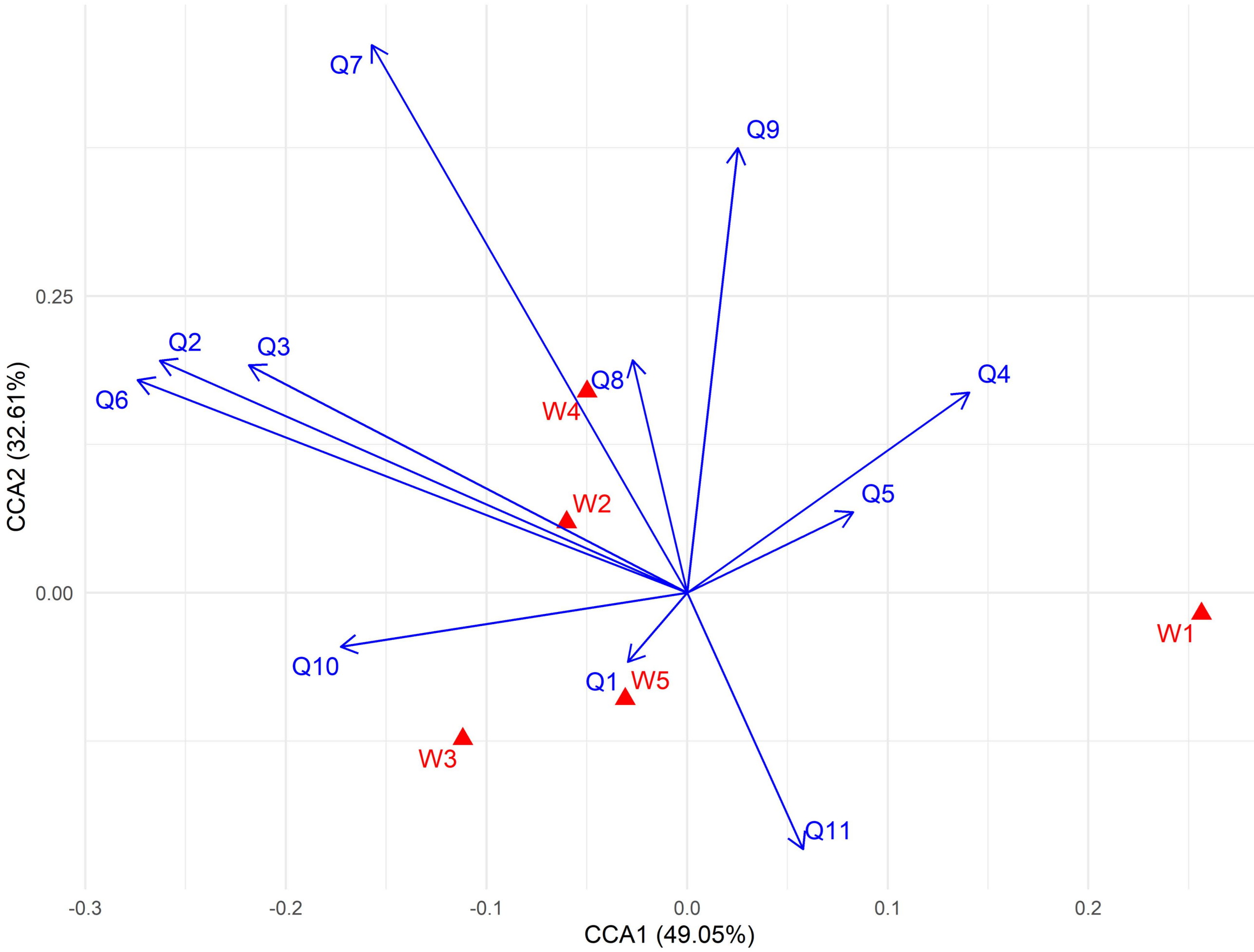

Figure 7. Canonical correspondence analysis (CCA) showing the relationship between the perception of the concept of a citizen scientist and issues related to the importance and limitations of citizen science. W = Words (represented by the red triangle). W1—participants; W2—volunteers; W3—data collection; W4—community; W5—society. Q = Question. Q1—How important is citizen science (CS) for scientific research? Q2—Does CS involve the public in the scientific research process? Q3—Are the data obtained by volunteers (citizen scientists) reliable? Q4—Can the data obtained by citizen scientists be useful for scientific research? Q5—Do CS initiatives facilitate and expand the collection of scientific data? Q6—Do CS initiatives allow society to have access to the results of scientific research? Q7—Are CS initiatives a tool for scientific dissemination? Q8—Do CS initiatives contribute to raising awareness among citizens about the importance of science in solving society's problems? Q9—Do CS initiatives function as a space for dialogue in which society presents demands to scientists to transform into an object of study? Q10—Do data collected by citizen scientists provide an economical solution for exploring research questions on a large scale? Q11—Do you believe that CS has limitations?

The results highlight that the predominance of human and exact sciences in associating citizen science with extension projects may highlight not only the social role of universities but also a resistance to accepting citizen science as an effective research method. In contrast, professors from the biological sciences field associated citizen science with open science, suggesting greater familiarity with open data practices and collaboration, which aligns with recent trends in biodiversity and conservation research.

The fragmented understanding of the concept of a citizen scientist across fields underscores the urgent need for transverse and interdisciplinary training on citizen science in the university curriculum. As suggested by Haklay et al. (2021), successful citizen science requires not only technical knowledge but also social sensitivity, communication skills, and an ethical commitment to inclusion.

Finally, the limited understanding of terms such as data collection and community indicates a fundamental gap: many professors still do not grasp that citizen science is a practice in which the community not only collects data but also contributes to formulating research questions, analyzing results, and actively participating in solving local problems (Bonney et al., 2009).

Reinforcing these interpretations, the results of the professors' perceptions of citizen science are deeply rooted in university extension activities and the democratization of scientific knowledge. This perspective reflects the continuation of a traditional view in which social participation is primarily valued as a strategy for disseminating academic knowledge, but is seldom recognized as an authentic process in the collaborative construction of scientific knowledge (Bonney et al., 2016; Strasser & Haklay, 2018).

The association between extension projects and the utility of citizen science data reinforces the notion that many professors perceive citizen science as an educational and social activity focused on popularizing science. However, this practice is not recognized as a robust procedure for scientific production. This limited perception may hinder the full integration of citizen science into research projects, thus restricting its transformative potential (Albagli et al., 2014).

On the other hand, the strong correlation between participatory research and the scientific importance of citizen science is a positive indicator. It suggests that a segment of educators recognize the epistemological value of citizen participation, aligned with the concept of the "co-creation" of knowledge (Haklay et al., 2021). This recognition is crucial for the consolidation of citizen science as an authentic scientific approach, rather than merely an educational or outreach tool (Newman et al., 2017).

The relationship between open science and public access to research results highlights a contemporary understanding of citizen science as a practice aligned with the principles of transparency and open access to data and science for all (Heigl et al., 2020). In this context, citizen science is seen as a component of open science, promoting not only the dissemination of data but also active participation in the production and interpretation of the scientific results (Bonney et al., 2016).

The recognition of citizen science as a "space for dialogue" (associated with action research and participatory science) further emphasizes the role of citizen science in strengthening the relationship between science and society (Kimura & Kinchy, 2016). This dialogue is central to more democratic models of science, which aim not only to inform the public but also to respond to specific social demands, promoting shared knowledge with diverse social actors (Strasser & Haklay, 2018).

However, the association of terms like society with the perception of limitations in citizen science reveals the presence of cultural and epistemological barriers. As noted by Riesch and Potter (2014), many scientists still view public participation with skepticism, questioning the quality and validity of data collected by non-experts. This skepticism may reflect the lack of training among educators in participatory methodologies, as well as the persistence of a hierarchical science model that values technical knowledge over practical experiences.

3.3. Analysis of Specific Characteristics of Citizen Science

3.3.1. Perceptions About Level of Public Engagement in Citizen Science

The results indicate that the most effective type of participation was the collaborative model (35.29%; $n = 60$), followed by co-created participation (26.47%; $n = 45$). In contrast, 14.71% of participants stated that they did not know/did not answer the question, and participants least frequently selected the contractual model (10.59%; $n = 18$), the contributory model (8.82%; $n = 15$), and the collegial model (4.12%; $n = 7$) (Figure 8).

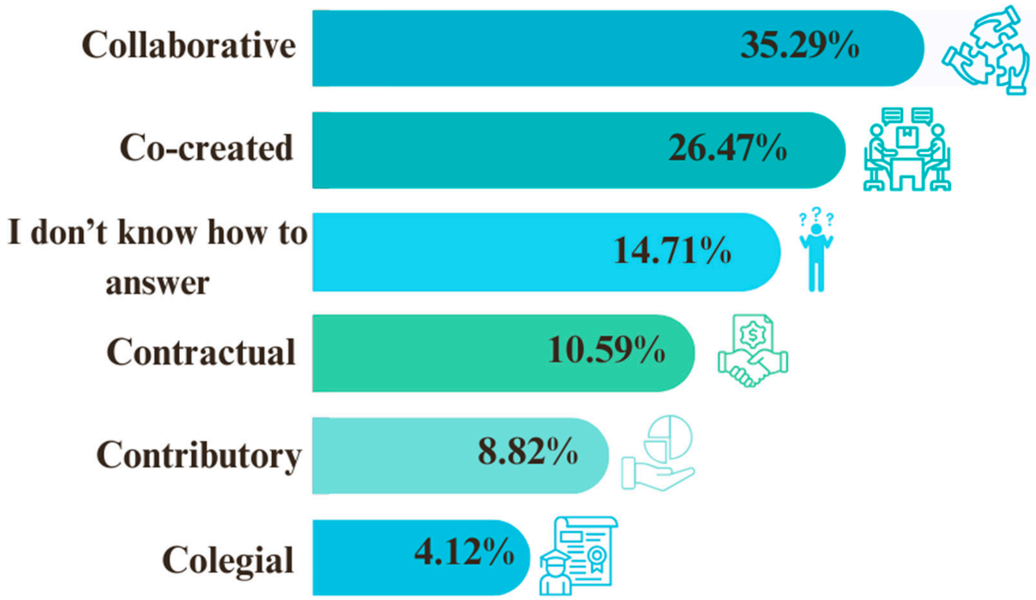

Figure 8. Perception of public engagement levels in citizen science projects.

The results reveal a marked preference for more collaborative forms of participation within citizen science. This trend suggests that participants value not only the opportunity to contribute data, but also involvement in more complex stages of the scientific process, such as methodological design, the analysis of results, and their dissemination (Bonney et al., 2009; Shirk et al., 2012). The prevalence of the collaborative model could be related to its balance between professional orientation and citizen involvement, offering a space where participants feel like an active part of the knowledge generated, without necessarily requiring specialized technical training (Aristeidou et al., 2017).

The recognition of the co-created model as another highly valued form reinforces this perspective, as it implies shared responsibility between scientists and citizens from project conception to implementation. This may indicate a growing public interest in more horizontal participatory experiences that recognize and validate their knowledge, concerns, and capabilities (Buytaert et al., 2014; A. Land-Zandstra et al., 2021). This type of engagement tends to strengthen the social appropriation of knowledge and trust in scientific processes (Strasser & Haklay, 2018).

In contrast, models such as the contractual, contributory, and collegial models were perceived as less effective, which could be interpreted as dissatisfaction with approaches that limit the role of citizens to peripheral tasks or position them as passive actors. In particular, the low appreciation of the contributory model is striking, as it has historically been the most widely implemented model in citizen science projects (Bonney et al., 2009;

Shirk et al., 2012). This result may signal a shift in public expectations, as the public is no longer satisfied with simply "helping scientists" but rather aspires to fuller and more meaningful participation (Hecker et al., 2018).

The significant number of people who stated they did not know or did not answer the question could be related to the conceptual complexity of the participation models or a lack of direct experience with these approaches (T. B. Phillips et al., 2019). This raises the need for greater clarity in communicating the types of participation and for training strategies that empower the public to recognize and exercise their role within science. Taken together, the results invite reflection on how citizen science projects can evolve toward more dialogic, inclusive, and transformative formats, aligned with the aspirations of the participants themselves and with the principles of socially engaged science (Shirk et al., 2012).

3.3.2. Perceptions of the Most Effective Methods for Communicating and Transmitting Data Produced by Citizen Scientists

Among the most efficient methods perceived by professors for sharing and transmitting data were sending videos and audio clips (17.15%; *n* = 35), using smartphone applications and sharing photos and images, both with 14.71% (*n* = 30), and sending documents online (13.24%; *n* = 27). A total of 12.75% (*n* = 26) of respondents did not know how/did not want to answer. Other less frequently cited methods included simple text messages (10.78%; *n* = 22), the use of manually completed data sheets (8.82%; *n* = 18), and other means of communicating and transmitting data, such as "brochures, books, reports, newsletters, questionnaires, interviews, guided tours, radio, Instagram, face-to-face, and group discussions" (7.84%; *n* = 16) (Figure 9).

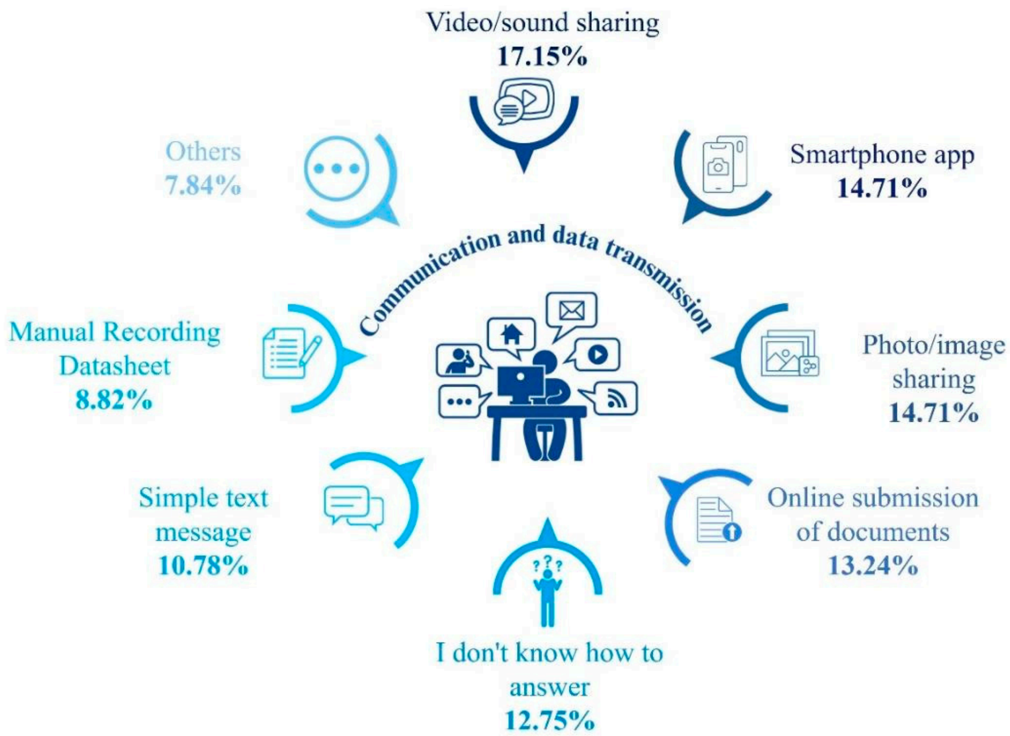

Figure 9. Perception of professors at Brazilian federal universities about the means of the communication and transmission of data produced by citizen scientists.

The results show that the methods perceived as most efficient for sharing and transmitting data were centered on the use of accessible and everyday digital resources, such as sending videos and audios, using mobile applications, sharing photos and images, and sending documents online. This preference reflects the key role of technological tools in citizen science, where digital platforms, social networks, and mobile applications have transformed the way participants record, share, and collaborate on scientific research (Catlin-Groves, 2012; Williamson et al., 2016; See, 2019; Spasiano et al., 2021). Furthermore, the use of resources that enable remote and real-time collaboration in accessible formats has been associated with increased scientific productivity and greater cohesion among participating communities (Newman et al., 2017; Haklay, 2015). The possibility of connecting geographically distant actors through technological tools not only avoids the duplication of efforts but also facilitates the replication of experiments and strengthens collaborative networks (Albagli et al., 2014).

Although to a lesser extent, more traditional methods such as text messaging, hand-completed data sheets, and other media such as brochures, interviews, and in-person discussions were also mentioned. This diversity of media suggests that while digital technologies dominate in the field of citizen science, there is still value in analog or hybrid formats, especially in contexts where digital connectivity may be limited, which is common in remote and underexplored areas, thus becoming valuable scientific resources (Cappa et al., 2022; Mazumdar & Thakker, 2020).

Finally, it is important to highlight that regardless of the methods selected for sharing information, it is essential to consider ethical aspects related to data privacy and security (Bonney et al., 2016; Bowser et al., 2017; Preece, 2016), as well as to guarantee the quality and rigor of the data generated through effective collaboration between citizen scientists and professionals (Kosmala et al., 2016; Kullenberg & Kasperowski, 2016).

3.3.3. Participants' Perceptions Regarding the Use and Dissemination of Data Obtained Through Citizen Science

When asked how they would use citizen science data, the majority of professors (74.71%, $n = 127$) stated that they would make the data available on an open-access platform, accessible to anyone interested. A total of 11.76% ($n = 20$) responded that they did not know how the data would be used or preferred not to answer, while 10.00% ($n = 17$) indicated that the data would be used in studies with their results published in scientific journals. A small number of professors (1.76%, $n = 3$) said the data would be made available exclusively to scientists and research team members, and a slightly smaller portion (1.18%, $n = 2$) mentioned alternative approaches, such as applying ethical principles to regulate access or considering the target audience. Finally, only one participant (0.59%, $n = 1$) reported that the data would be used in technical reports. Notably, none of the respondents expressed disagreement with the idea of publishing the data (Figure 10).

The preference among professors for using accessible and widely used digital tools to share and transmit data is consistent with their expressed interest in making citizen science data openly available. This alignment suggests a clear understanding of the principles of open science, in which citizen science plays a central role (Albagli et al., 2014). The prioritization of open-access platforms reflects an orientation toward transparency, participation, and the democratization of knowledge—hallmarks of the open science movement, which advocates for unrestricted access to scientific publications, data, tools, and educational methods (Besançon et al., 2021; Edwards-Schachter, 2024).

Furthermore, the recognition of scientific publications as a valid use for citizen-generated data points to an appreciation of the potential for collaboration between professionals and non-specialists throughout the research process (Dickinson et al., 2012; Shirk et al., 2012). This view reinforces the notion that citizen engagement is not limited to data collection but can extend to knowledge production and dissemination (Haklay et al., 2021; T. B. Phillips et al., 2019).

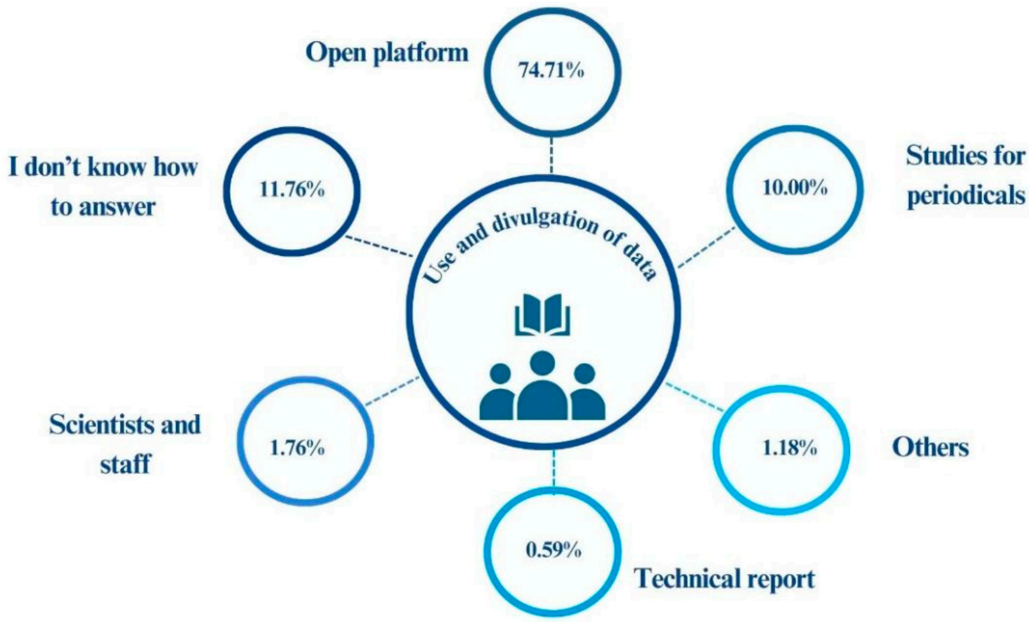

Figure 10. Perception of the use and dissemination of data obtained by citizen science initiatives from the professionals' perspective. Each participant gave more than one answer.

It is also noteworthy that relatively few respondents mentioned technical reports or restricted access to data, while some emphasized the importance of ethical considerations and public engagement. This tendency underlines a shift toward prioritizing community involvement and the responsible circulation of knowledge among participants and broader audiences. As noted by Albagli et al. (2014), making primary data publicly available is essential not only for ensuring reproducibility and reuse but also for maintaining scientific integrity and fostering trust in science. In addition, this process helps to identify inconsistencies, low quality, plagiarism, and fraud (Tennant et al., 2016).

3.3.4. Perceptions of How Volunteer Participation (Citizen Scientists) Is Acknowledged in Scientific Publications

The majority of educators (27.06%, n = 46) indicated that they would mention the volunteers by name in their publications, including them as co-authors of the project. Another 15.29% (n = 26) did not know how to answer, while 13.53% (n = 23) opted for a non-name mention and 11.76% (n = 20) indicated that the contribution would be acknowledged in the acknowledgments. A small portion (4.71%, n = 8) stated that the type of recognition would depend on the level of involvement of the volunteers. And only 0.59% (n = 1) stated that they would not mention the participation of citizen scientists in publications (Figure 11).

The responses regarding how educators would recognize the contributions of citizen scientists align with the broader trend observed in their preferences for open communication, transparency, and inclusive participation described in the previous sections. Most educators expressed a willingness to give due credit to their volunteers—either through co-authorship, direct mention, or formal acknowledgments in publications. This indicates a clear awareness of the importance of recognition in fostering sustained engagement and a sense of ownership among participants (Raddick et al., 2013; Singh et al., 2014; Unell & Castle, 2012).

Acknowledging volunteers appropriately is not only a matter of ethics but also a strategic element for enhancing motivation and long-term commitment to citizen science projects. As noted by West and Pateman (2016), ongoing communication—such as newsletters, updates on project outcomes, and invitations to training—can serve both to recognize contributions and to reinforce community engagement. This is especially relevant when the contributions of volunteers vary in intensity or complexity, requiring flexible forms of recognition based on their level of involvement (Garner & Garner, 2011; O'Brien et al., 2010).

Moreover, the emphasis placed by some respondents on adjusting recognition according to participation level reflects an effort to ensure fair and context-sensitive crediting. This is in line with recommendations from the literature that call for the increased visibility of citizen contributions, whether through formal acknowledgments, keywords in publications, or co-authorship when justified (Haklay, 2015; Riesch & Potter, 2014; Hecker et al., 2018). Such practices contribute not only to individual motivation, but also to the integrity and transparency of citizen science as a collaborative and inclusive research approach (Silvertown et al., 2013).

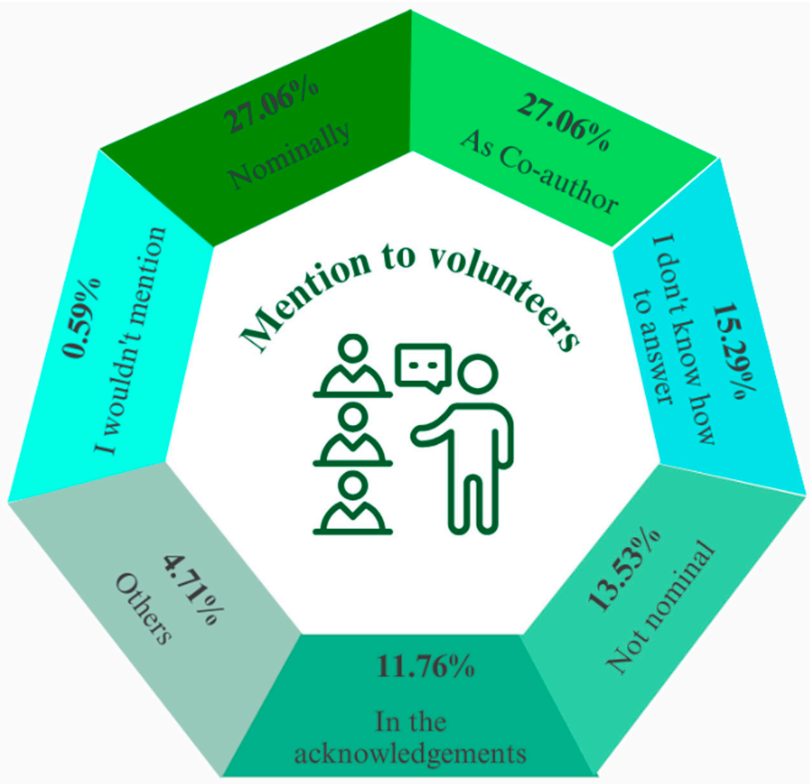

Figure 11. Types of mention of the participation of volunteers (citizen scientists) in scientific publications. The percentages were calculated based on the total number of responses for each criterion. Each participant gave more than one response.

3.3.5. Perceptions of Priority Audience Types for Participation in Citizen Science Projects

Among the audiences the professors identified as priorities for participation in citizen science projects, Indigenous populations (19.63%) and quilombolas (20.64%) stood out. Primary school students (18.51%) were also frequently mentioned, and to a lesser extent, secondary school students (13.52%). A total of 9.96% of respondents indicated they did not know which audience to involve. Other groups mentioned less frequently included primary school teachers (4.98%), fishermen (3.56%), urban residents (2.85%), and secondary school teachers (1.78%). Rural residents, such as farmers and ranchers (0.71%), as well as riverside residents (0.36%), were also mentioned. The "other" option (3.20%) included observations on the need to adapt the audience according to the type of research, topic, and content, as well as suggestions related to the training and education of participants (Figure 12).

The groups identified by professors as priorities for participation in citizen science initiatives reflect an understanding aligned with inclusive and transformative approaches to knowledge production. The frequent mention of Indigenous and quilombola populations, as well as primary and secondary school students, underscores the recognition of diverse social actors as legitimate contributors to scientific processes. This perspective resonates with Albagli and Iwama (2022), who argue that acknowledging the right of individuals and communities to participate in all stages of research fosters new scientific approaches and enhances social learning.

The emphasis on traditionally underrepresented groups, such as Indigenous peoples and quilombolas, aligns with the proposition by Stevens et al. (2014) that citizen science must be inclusive, democratic, and far-reaching. According to Comandulli et al. (2016), any community—regardless of geographic or socioeconomic conditions—should be empowered to engage in projects that address local challenges. In this sense, the presence of traditional populations in the responses can also be understood in light of their proximity to biodiverse ecosystems and the richness of their traditional ecological knowledge, which plays a crucial role in species conservation and territorial management (Da Silva et al., 2025b; Da Silva et al., 2025a; Guerrero-Moreno et al., 2024).

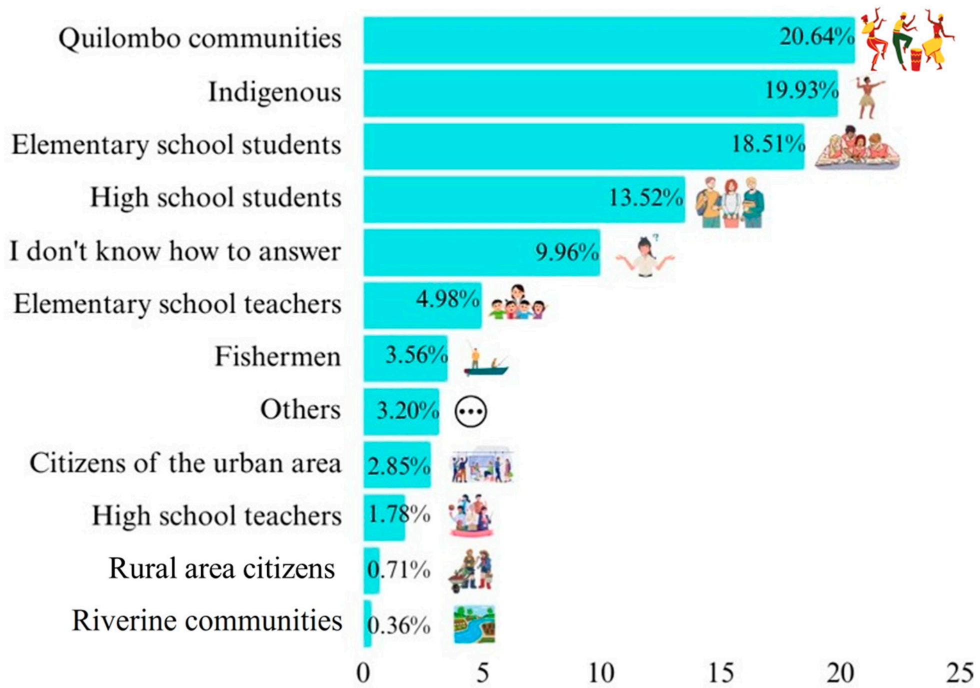

Figure 12. Professors' perception of the types of audiences prioritized for participation in citizen science projects. Each participant could assign more than one answer.

The mention of students and educators as target audiences also suggests a pedagogical potential for citizen science, reinforcing the value of early engagement in scientific activities. Experiences such as the Citizen Science for the Amazon project show how citizen scientists from rural communities can act as informed and trained agents in monitoring and protecting ecological systems (Eyng et al., 2022). Similarly, the WeatherBlur project illustrates how collaboration between scientists and community members—such as fishermen, students, and teachers—can generate meaningful data and interpretations on issues of local environmental relevance (Kermish-Allen et al., 2019).

The inclusion of suggestions regarding audience adaptation and the need for participant training, reported under the "other" category, also highlights an awareness among educators of the importance of tailoring engagement strategies to each research context. This supports the notion that citizen science must remain flexible and responsive to the needs, capacities, and knowledge systems of the communities involved.

3.3.6. Perceptions of Training and Qualification Methods for Citizen Scientists

The survey results indicate that most professors, when considering working with citizen science, would use some training or qualification method for their participants. Specifically, 84.12% (*n* = 143) would apply training before the research, while 12.94% (*n* = 22) did not know how to answer and only 2.94% (*n* = 5) indicated they would not apply training (Figure 13a). Regarding the training method adopted, practical training was the most frequently mentioned by 35.95% (*n* = 110) of professors, followed by courses (33.33%, *n* = 102) and lectures (18.63%, *n* = 57). A percentage of 8.82% (*n* = 27) was unable to specify, while 3.27% (*n* = 10) suggested varied approaches, such as "conversations/meetings, action research, specific projects, ongoing training, participatory methodologies, PDF tutorials, videos, social networks, and workshops" (Figure 13b).

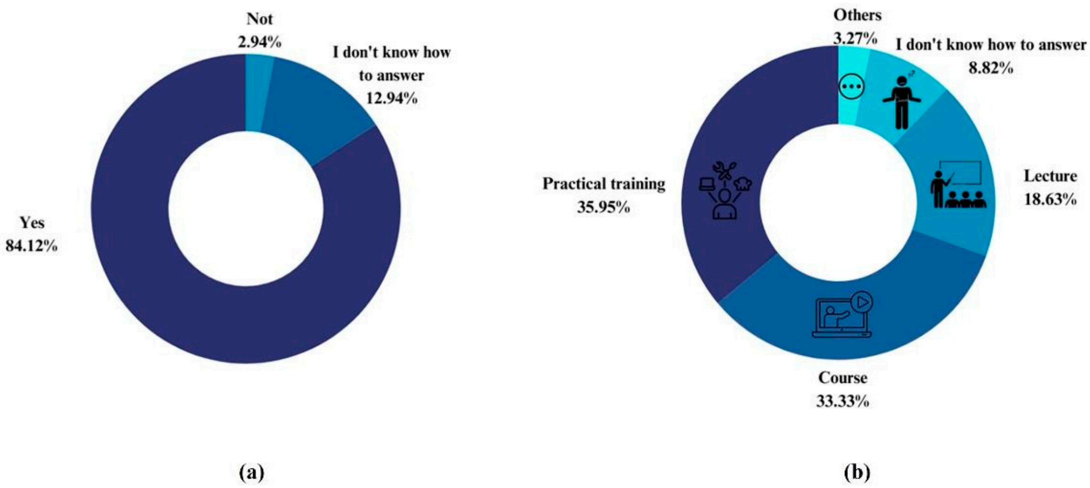

Figure 13. (**a**) Perceptions of teaching professionals on the use of some training/qualification methods with citizen scientists. (**b**) Training/qualification methods used by professors with participants.

Most researchers recognize the importance of training and professional development for citizen science volunteers (Burgess et al., 2017). The knowledge, skills, and abilities acquired are essential to guarantee the quality and reliability of the data collected, in addition to ensuring that the volunteers understand the correct procedures and maintain ethics in data collection (Kooli, 2023; Kosmala et al., 2016). Researchers' perceptions of the use of training and development methods may vary according to factors such as the nature of the research, social and local context, and previous experiences with citizen science projects (Aristeidou et al., 2021; Dickinson et al., 2010).

Furthermore, experts highlight the importance of standardization and uniformity in training, methodologies adapted to the target audience, accessible and engaging practices, and encouraging cooperation between researchers and volunteers in the exchange of knowledge (Kiss et al., 2022; Zettler et al., 2017). The continuous evaluation of training methods and the inclusion of technologies also facilitates the interaction, accessibility, and advancement of scientific initiatives (Haklay, 2015; Bonney et al., 2016; Buytaert et al., 2014).

A combination of educational and practical actions is necessary to prepare volunteers to collaborate effectively in scientific research (Resnik et al., 2015). These actions include face-to-face training such as lectures, workshops, and seminars, in which volunteers learn directly from researchers (Bonney et al., 2009; Haklay, 2015; Ono et al., 2018), as well as online training through virtual platforms and courses accessed through modules, videos, and various technological resources that facilitate the understanding of scientific concepts and the tasks to be performed (Lee et al., 2016; Liu et al., 2021; Van Haeften et al., 2021).

An effective method for gaining practical experience is training that instructs volunteers in sample collection and analysis, field observations, and the use of professional equipment (Dickinson et al., 2010; Pocock et al., 2014). Complementary resources, such as manuals, guides, individualized guidance, discussion groups on social networks, periodic meetings, the submission of papers, ongoing monitoring, and recognition, are essential to ensure that volunteers are prepared to contribute to CS and ensure their permanence in scientific projects (Aristeidou et al., 2021; Meyer et al., 2020; Snyder, 2017).

3.3.7. Perceptions About Preferences for Data Collection Methods Used by Citizen Scientists

Regarding data collection by citizen scientists, the majority of professors (45.29%, *n* = 77) prefer a standardized approach. A total of 33.53% (*n* = 57) of respondents opted for a combination of opportunistic and standardized approaches, and a smaller portion of professors (16.47%, *n* = 28) were unwilling/unable to respond. Only 4.71% (*n* = 8) opted for opportunistic collection (Figure 14).

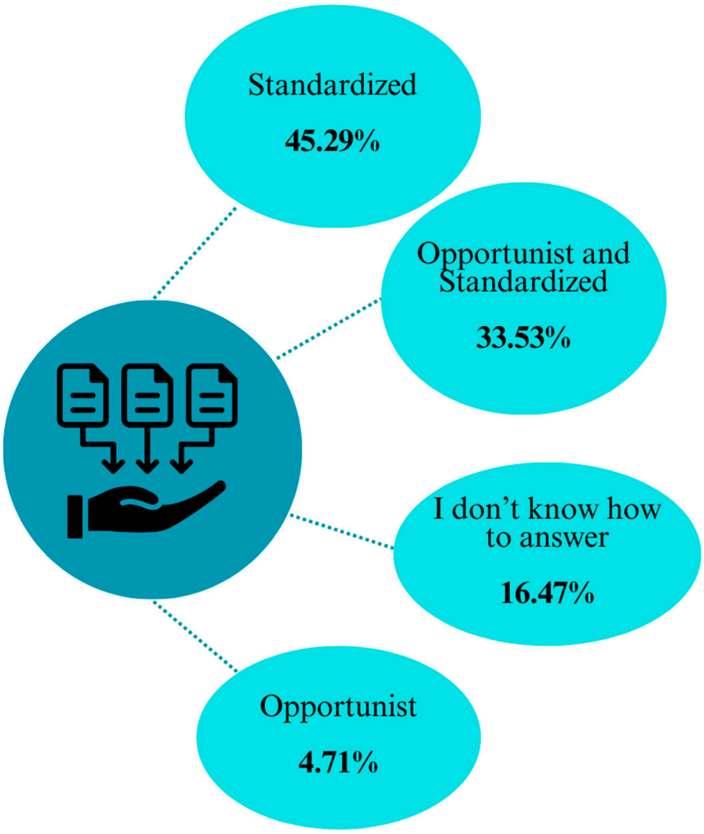

Figure 14. Professors' preference regarding the form of data collection by citizen scientists.

The preferences expressed by educators regarding the method of data collection in citizen science projects indicate a tendency toward more structured and reliable approaches. Many projects designed by experts include different levels of volunteer involvement but often rely on standardized methodologies to ensure consistency and scientific rigor (Bonney et al., 2016; Pinto et al., 2020). This preference for standardized data collection reflects an awareness of the importance of methodological consistency, especially in projects where data quality is essential for scientific validity (Brown & Williams, 2019; Dickinson et al., 2010; Thiel et al., 2014; Pinto et al., 2020). Such approaches typically require participants to undergo prior training or accumulate experience to minimize errors and ensure accurate data collection (Crall et al., 2010; Strobl et al., 2020; Pinto et al., 2020).

At the same time, a portion of respondents showed an openness to integrating opportunistic strategies alongside standardized ones, suggesting a flexible understanding of the varying contexts and capacities in which citizen science occurs. Opportunistic data collection, while less rigorous, can be valuable for gathering large volumes of observations without requiring strict adherence to methodological protocols (Riesch & Potter, 2014). However, such data are often met with skepticism, particularly when used in scientific analyses that inform policies or decision-making, due to the absence of clear research questions or documentation of participant effort (Lewandowski & Specht, 2015; Golumbic et al., 2017). These concerns underscore the importance of transparency and scientific credibility in how volunteer-generated data are received and interpreted by the broader academic community (Riesch & Potter, 2014).

Moreover, the choice of a data collection method must also take into account the characteristics of the participants—such as their motivation, previous experience, and capacity to follow instructions—as these factors directly influence the quality of the data produced (Jordan et al., 2012). Elements like recruitment, training strategies, and survey design are fundamental to the success of citizen science projects (Lewandowski & Specht, 2015). Evidence suggests that scientific outcomes are improved when volunteers receive ongoing training, use simplified protocols, and engage in peer-validation processes (Riesch & Potter, 2014).

3.3.8. Perceptions of Methods and Tools Used to Evaluate the Efficiency of Citizen Scientists

To assess the effectiveness of citizen scientists' participation in the research, the results indicate that more than half of the respondents (54.12%, $n = 92$) showed interest in using some method or tool. A significant portion (38.23%, $n = 65$) did not know how to answer. On the other hand, only 7.65% ($n = 13$) of the professors indicated that they would not use any method to assess the effectiveness of citizen scientists' participation (Figure 15a). Regarding the methods and tools to assess the participation of citizen scientists, the questionnaire was the most frequently cited, with 20.65% ($n = 19$) of the responses, followed by the evaluation meeting (11.96%, $n = 11$) and interview (9.78%, $n = 9$). Other less frequently used methodologies included online questionnaires, discussions, tests, and statistical analysis, with 4.35% ($n = 4$) for each, in addition to reports (1.08%, $n = 1$), mentioned less frequently (Figure 15b).

Evaluation plays a key role in improving citizen science projects, enhancing both the quality of the collected data and participants' experiences (Bonney et al., 2016; Dickinson et al., 2012; Kosmala et al., 2016). The willingness of respondents to use some method or tool to assess citizen scientists' participation reflects an increasing recognition of the importance of evaluation within these initiatives. At the same time, uncertainty or hesitation among some respondents may be linked to a lack of familiarity with the available tools or the absence of an established evaluation culture (Conrad & Hilchey, 2011; Riesch & Potter, 2014; Kobori et al., 2016). This highlights the need to promote greater awareness of how evaluation can help identify challenges, demonstrate outcomes, and strengthen volunteer engagement (Newman et al., 2017).

Among the methods and tools mentioned, questionnaires were cited most frequently, followed by evaluation meetings and interviews. These instruments are widely recognized in the literature for their usefulness in assessing the expectations, prior knowledge, motivation, learning, and long-term contribution of participants (A. M. Land-Zandstra et al., 2016; T. B. Phillips et al., 2019; Thiel et al., 2014). Evaluation meetings also provide opportunities to analyze participants' competencies, research skills related to data collection and analysis, and ability to communicate scientific information (Dickinson et al., 2012; Kosmala et al., 2016; Newman et al., 2017). These processes may involve self-assessment, feedback from project coordinators or facilitators, or the use of specific tools, such as online questionnaires, tests, reports, and statistical analysis (Aristeidou & Herodotou, 2020; Bonney et al., 2009; Brossard et al., 2005; Lewandowski & Specht, 2015).

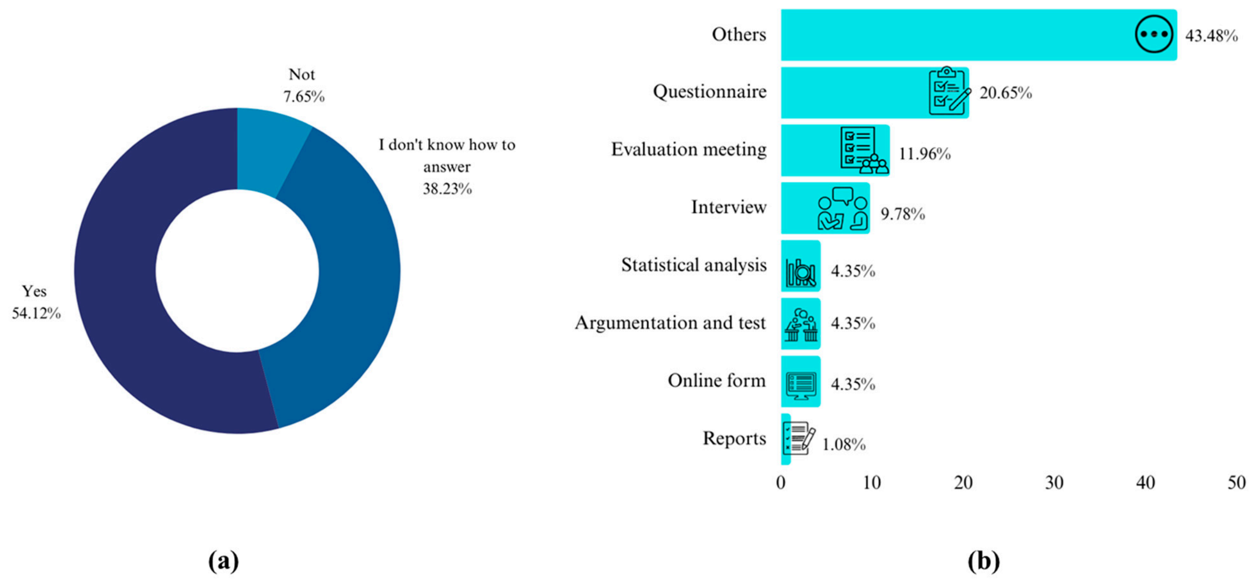

Figure 15. (**a**) Perception of teaching professionals about the use of some method/tool to evaluate the efficiency of citizen scientists' participation. (**b**) Method/tool used to evaluate the efficiency of citizen scientists' participation before and after the research.

Therefore, the choice of evaluation methods should be aligned with the specific objectives of each project, the research focus, and the characteristics of the participants. Using a combination of approaches can provide a broader and more meaningful understanding of the effectiveness of citizen scientists' participation, supporting continuous improvements in citizen science initiatives (Bonney et al., 2009; Bonney et al., 2016; Shirk et al., 2012).

3.3.9. Perceptions Regarding the Need for the Validation of Data Collected by Citizen Scientists by Professional Scientists

The results show a greater need for data verification by professionals (51.76%, $n = 88$), and a significant group of respondents (26.48%, $n = 45$) believed that it is not necessary to validate and/or confirm data. Furthermore, 21.76% ($n = 37$) did not know how to answer (Figure 16).

The quality of the data collected by citizen scientists is a central concern for researchers engaging with public participation in scientific research (Burgess et al., 2017; Fraisl et al., 2022; Jollymore et al., 2017). The results indicate that a considerable portion of respondents recognized the importance of expert data verification, highlighting the perceived need to ensure scientific reliability in citizen science initiatives. This aligns with findings in the literature, where the validation and verification of data by professionals are essential to strengthen researchers' and reviewers' trust in the outcomes of such projects (Callaghan et al., 2021; Mitchell et al., 2017).

At the same time, a notable group of respondents expressed the view that data validation may not always be necessary, possibly reflecting a belief in the competence of well-trained citizen scientists or in the robustness of the project design. This divergence of perceptions underscores the diversity in expectations and practices across different citizen science contexts, particularly when considering the varied levels of expertise among participants (Wiggins et al., 2011).

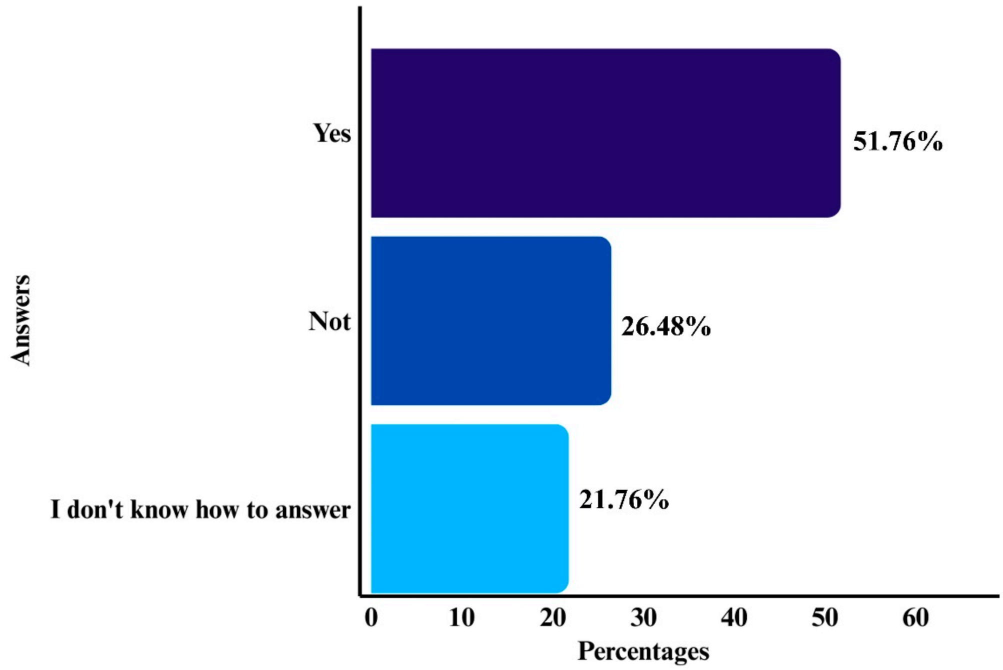

Figure 16. Professors' perception that data collected by citizen scientists must be validated or confirmed by professional scientists.

In ecological and environmental research, expert validation remains a common and often necessary component, ensuring the reliability of species identification and ecological observations (Baker et al., 2021; Fraisl et al., 2022; Kosmala et al., 2016). For instance, Falk et al. (2019) demonstrated that observer identification skills could be effectively assessed and confirmed through expert validation. Similarly, Gardiner et al. (2012) showed that when citizen-collected data are reviewed by professionals, the process can be more cost-effective than traditional scientific data collection methods.

In addition to data quality, there is a growing need to explore whether citizen participation in science can also influence other essential scientific skills, such as selecting appropriate research methodologies, using control groups, and analyzing evidence (T. Phillips et al., 2018). As citizen science continues to expand its role in democratizing scientific knowledge, future efforts may support the development of critical thinking skills and contribute to a more informed and scientifically literate public (Becker-Klein et al., 2016).

4. Conclusions

Regarding citizen science (CS), professors demonstrated a largely favorable view, recognizing its potential to expand scientific knowledge, promote scientific literacy, and contribute to the democratization of science. However, most respondents were not directly involved in citizen science projects. The main concern of professors, as exposed in the open-ended responses and confirmed by more than half of the participants on the Likert scale, was the reliability of the data produced by non-scientist collaborators, perceived as a relevant limitation.

Regarding the engagement of non-scientists, the professors highlighted the importance of voluntary participation in activities such as data collection, analysis, and dissemination. In addition, they suggested standardizing data collection protocols and providing adequate training for volunteers. The inclusion of marginalized social groups, such as students, Indigenous people, and quilombolas, was pointed as an important strategy for the co-production of knowledge and for solving local problems.

In this context, it is important to highlight that the favorable view of professors toward citizen science may be partially related to the epistemological paradigms that guide their research practices. Researchers aligned with socio-constructivist perspectives tend to adopt participatory approaches and value the co-creation of knowledge with non-specialists. This trend has been widely observed in social science studies in Europe, where citizen and community involvement in the scientific process has been encouraged, including through increased funding from the European Union for collaborative research projects. Recognizing the epistemological foundations that influence attitudes toward citizen science is crucial to better understanding the opportunities and challenges involved in strengthening public participation in scientific processes.

The findings of this study can contribute to the development of academic policies that encourage greater diversity and inclusion in research, particularly in areas involving citizen science. Strengthening training programs for citizen scientists and adopting more robust methodologies to ensure data quality are essential steps toward expanding the practice of citizen science in Brazil and worldwide.

Citizen science needs to be shown as a key process emerging within higher education institutions to effectively open science and make technology available with a meaningful purpose to our global society. These initiatives are more necessary than ever to empower society, based on scientific knowledge, to adopt a positive attitude to global challenges. While opening up access to data, publications, and other research products is necessary, it is insufficient to fully transition science toward open science. Citizen science provides the means for open, holistic, and participatory processes of knowledge generation. Therefore, CS should be acknowledged as an essential pillar of open science to enable it to add significant value. Citizen science, with its long tradition of public involvement in research, must be recognized as contributing to the ultimate mission of universities in co-producing scientific research with potential benefits for each individual and society.

5. Limitations and Future Perspectives

5.1. Limitations

This study presents important contributions to the understanding of higher-education faculty members' perceptions of citizen science, but some limitations should be considered. First, convenience sampling limits the scope of the results, since participants were selected from among those who were available to respond to the questionnaire. This may have generated a restricted view of participation, since faculty members more engaged in citizen science or specific to the topic may be underrepresented. In addition, the research only covers federal universities, disregarding faculty members from state, municipal, and private universities, also limiting the generalization of the results. Another limitation is the prevalence of quantitative methods, which, although they allow for robust statistical analysis, are unable to capture the in-depth nuances of faculty members' perceptions and experiences, in contrast to more elaborate qualitative interviews. Finally, the lack of more extensive monitoring prevents the observation of possible changes in professors' perceptions over time, especially as new citizen science activities develop in higher education institutions and more researchers adopt the practice in their projects.

5.2. Future Perspectives

In view of the limitations and findings of this study, some future expectations are suggested to deepen the topic. First, expanding the research to include professors from state, municipal, and private universities could provide a more general view of citizen science in Brazil. In addition, the adoption of a shared methodology, combining questionnaires with in-depth interviews, could offer a more detailed understanding of the motivations, barriers, and experiences of professors with citizen science. Another relevant aspect is to conduct more extensive studies to monitor the progress of professors' perceptions over time, especially in response to specific institutional practices to popularize citizen science. It is also necessary to offer training and awareness programs for professors who are unaware of or do not practice the best methodologies on citizen science, encouraging the adoption of more collaborative practices. Finally, exploring the relationship between citizen science and public policies can strengthen the institutional recognition of this practice, contributing to the democratization of scientific knowledge and the engagement of different social actors, including quilombolas and Indigenous people, as highlighted in this research. In addition, exploring new models of collaboration between academia and the community using innovative technologies can be a way to overcome the limitations identified and increase the reliability and effectiveness of citizen science projects.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/educsci15060738/s1, Figure S1: Flowchart of the phases of involvement of research on citizen science from the perspective of Brazilian higher education professors. Questionnaire S2: Questionnaire designed to assess the perception of professors at Brazilian federal universities about citizen science.

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Data Availability Statement: Research data can be provided by the authors upon request.

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Abbreviations

The following abbreviations are used in this manuscript:

CS	Citizen Science
EBTT	Higher Education or Basic, Technical, and Technological Education
IBGE	Brazilian Institute of Geography and Statistics
ICF	Informed Consent Form
MEC	Ministry of Education
OPAL	Open-Air Laboratory
PDF	Portable Document Format
PhD	Doctorate
REC	Research Ethics Committee
UNESCO	United Nations Educational, Scientific, and Cultural Organization

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