

Article

Evaluation of a Bee-Focused Citizen Science Training Process: Influence of Participants' Profiles on Learning

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Abstract: In citizen science, training and evaluation are important steps in improving the pedagogical effectiveness of projects. However, evaluating learning outcomes is complex and usually requires multidimensional analysis. In this work, we analyze the influence of the profile of citizen scientists (i.e., gender, age, level of education, educational background, prior experience in beekeeping, and level of contact with nature) on their learning, considering multiple dimensions (i.e., knowledge of the nature of science, self-efficacy, knowledge of scientific process and content, interests, values and priorities, and motivations). Citizen scientists participated in a training course that focused on meliponiculture and citizen science, and they performed a contributory citizen science protocol. The evaluation was based on pre- and post-course questionnaires, (reaching 886 respondents). Learning was observed in all dimensions and, depending on the dimension, profile variables, such as gender, educational level, educational background, and prior experience in meliponiculture were influential. Participants demonstrated high levels of nature connectedness, strong personal norms, pro-environmental behavior(al intention), and high levels of trust in science. The main motivations of the participants were to learn, assist in conservation, and contribute to the production of scientific knowledge about bees. Our findings offer insight into the subsequent steps and future training courses for the #cidadãosf citizen science project, but they could also be beneficial to other initiatives, indicating the importance of the evaluation of volunteer profiles to guide improvements in a project's quality.

Keywords: volunteer assessment; stingless beekeeping; learning evaluation; learning outcomes; profile



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1. Introduction

Citizen science approaches can be defined as the active engagement of the general public in different steps of scientific inquiry to produce new scientific knowledge [1]. Volunteer participation in scientific tasks has a history that spans centuries [2], although the term citizen science was only coined in the scientific literature in the 1990s, and the popularity of this field has been steadily growing ever since.

Learning outcomes in citizen science projects are typically multifaceted, spanning cognitive, affective, and behavioral domains [3]. On a cognitive level, participants are expected to enhance their scientific literacy, developing a stronger understanding of scientific principles, methods, and the subject matter at hand. This includes gaining knowledge about data collection techniques, data analysis, hypothesis testing, and the processes that

underpin scientific discovery [4–8]. On an affective level, participation in citizen science projects may increase individuals' interest in and appreciation for science, fostering a deeper connection with the natural world and a heightened sense of environmental responsibility [6]. Behaviorally, engagement in citizen science projects potentially stimulates the application of scientific knowledge in everyday life, promotes more environmentally friendly behaviors [9–12], and encourages continued participation in scientific endeavors. Lastly, engaging in citizen science often brings with it expectations of developing essential communication and collaboration skills, which are crucial for building communities around scientific topics, and fostering broader societal engagement in science [13].

Although the assessment of learning outcomes is not the focus of most citizen science research [14,15], evaluation is an important step in improving the pedagogical effectiveness of citizen science projects [16]. Therefore, it is imperative to unravel the determinants of successful learning outcomes, and a central point of investigation in this context is the potential correlation between the profiles of participants, encompassing demographic, academic, and professional characteristics, and their learning progress [17]. For example, engagement and learning in science and citizen science activities can be influenced by gender [18], previous contact with nature [19,20], or educational background [21,22].

In a systematic review that examined the scientific literature on citizen science initiatives centered on bee studies, Koffler et al. [23] found several studies that primarily evaluated participants. For example, MacPhail et al. [24] found that the participants in the Bumble Bee Watch citizen science project reported an increased awareness of species diversity (77%) and an improvement in their identification skills (84%). The authors observed that there was no significant difference in the number of photos submitted by age group or by type of area (urban/suburban/rural); they highlighted the importance of assessing the profiles of volunteers to maximize their retention and data quality. The authors showed that the participants were highly motivated by the desire to contribute to scientific data collection, help save bumble bees, further their own education, and for social reasons.

In Brazil, the citizen science project #cidadãoaaf (which can be translated as "stingless bee citizen") aims to study the flight activity patterns of stingless bees; it periodically promotes training courses for participants (the general public), addressing topics such as bee diversity, meliponiculture, and citizen science. Stingless bees constitute a group of eusocial bees that are important honey producers, being responsible for visiting and potentially pollinating up to 90% of plants in certain regions, making them crucial for the conservation of native areas and agroecosystems. They are part of the Meliponini tribe, which encompasses over 600 valid species worldwide, with approximately 400 occurring in the Americas and around 300 in Brazil [25]. The cultivation of stingless bees is known as meliponiculture, regardless of whether its purpose is commercial, hobbyist, or conservation-oriented. Meliponiculture is an activity that dates back to the indigenous peoples of the Americas but has been systematized since the second half of the 20th century and has gained popularity in Brazil over the past decade [26]. Meliponiculture, while economically promising through product sales, pollination services, and the trade of bee colonies, delivers benefits beyond monetary gain. It helps preserve ancestral values in traditional and indigenous communities, fosters social inclusion and empowerment for marginalized groups, and strengthens community bonds among meliponists. Environmentally, with proper guidance, it can aid in conserving endangered species, sustaining pollination-dependent plants, and enhancing local environmental quality [27]. Individuals engaged in meliponiculture are referred to as meliponists. On the other hand, one of the challenges most frequently identified by meliponists is the limited access to general knowledge and management skills [28]. Therefore, promoting training courses and evaluating learning outcomes can be pivotal in equipping these individuals with the knowledge and skills needed for participating in scientific discourses, engaging in sustainable beekeeping practices, and making meaningful contributions to their communities.

In this context, we sought to examine the hypothesis that the profile parameters (such as gender, age, educational background, level of contact with nature, and being a meliponist

or not) of the participants of project #cidadãoasf can influence their learning outcomes, related to their participation in the training course. The results of this study will provide insight into how CS training processes and participant profiles influence learning outcomes and, consequently, will help us improve the future educational strategies of our project. We believe that our findings can inspire other CS projects as well.

2. Materials and Methods

2.1. Training and Data Collection Context

The 4th iteration of the Outreach Course in Meliponiculture and Citizen Science, a partnership between the University of São Paulo and the Federal University of ABC, took place from 17–28 February 2022. The three-week online course content covered the fundamentals of bee biology and its importance to ecosystems, the management of stingless bees, meliponiculture (from the basics to relatively advanced topics), its products, principles of scientific thinking, and citizen science. After the theoretical classes of the course, the participants were invited to execute the flight activity monitoring protocol for stingless bees, which was titled the #cidadãoasf project [23,29]. All classes were pre-recorded, and synchronous interactions with the participants were provided through live sessions to answer questions and discuss topics of interest. The course was primarily advertised through the social media channels of the BeeKeep project, the meliponicultura.org initiative, and via the institutional communications of the University of São Paulo. This information was then disseminated across other communication platforms, including newspapers and blogs. The promotional materials provided all relevant details, e.g., the course was free, held online, and necessitated a steady internet connection. Originally, the participant limit was set at 500. However, it was later decided to accept all registrations. The authors of the study played various roles throughout the course, including the development of the monitoring protocol (as detailed in Leocadio et al. [29]), generating course content, configuring the online platform, and delivering both lectures and live broadcasts. Certain lectures and corresponding live broadcasts featured subject matter experts as guests.

The course entailed 25 h of pre-recorded lectures, delivered over three weeks. During this time, eight live broadcasts were organized to address participants' queries related to the course content. The citizen science protocol was introduced in a lecture at the end of the second week, and a question-and-answer session was conducted at the start of the third week. Following the conclusion of the lectures, participants were given an extra two weeks to carry out the bee monitoring and counting activities.

The training for the #cidadãoasf monitoring protocol consisted of (1) pre-recorded videos, (2) instructions available in an eBook [23], and (3) online live sessions to answer participants' doubts. In addition, an online forum was available for participants to pose questions and start discussions. All Supporting Materials highlighted the theoretical context of the project (environmental factors influencing bee flight activity), the research question being investigated (e.g., what time of day are bees most active?), and a detailed description of each step of the protocol. The citizen science protocol consisted of monitoring the flight activity of bees and submitting the data to an online platform (<https://beekeep.pcs.usp.br/>, accessed on 29 July 2023, in Portuguese). Participants provided information about the stingless bee nest, location, date, time, and weather conditions for each monitoring session. The monitoring consisted of recording 30-second videos of the nest entrances and then counting the number of active bees. The final class of the course focused on discussing with the citizen scientists the results of both the biological findings and their experiences participating in a scientific project.

A questionnaire was applied (via Google Forms) to assess the profiles and learning of citizen scientists. The initial application of the questionnaire (hereafter, we will call it the pre-questionnaire) was conducted before the course and the second application (hereafter, post-questionnaire) occurred upon course completion. The same questions were asked in the pre- and post-questionnaires. Only participants who completed all the course modules

had access to the post-questionnaire. The questionnaires were in Brazilian Portuguese and took about 10 to 15 min to complete.

2.2. Ethical Aspects

Before the beginning of the course, the participants were informed about the goals of our research project and were asked to complete a free and informed consent form (approved by the University of São Paulo Ethics Committee, number CAEE 53398721.9.0000.5390) and only responses from participants who agreed with the terms were included in the analyses. The course had 1112 participants who completed all classes and activities, of which, 919 agreed to the informed consent form and authorized the use of their anonymized responses for scientific research. Of these, we also excluded minors (under 18 years old), reaching $n = 886$ (see Supplementary Material 01).

2.3. Dimensions of Learning Assessment

The profiles of the citizen scientists and some aspects related to seven learning dimensions (Table 1) were assessed, considering the framework proposed by Phillips et al. [30], adapted to our context, as follows:

Profile: The first part of the survey evaluated certain characteristics of citizen scientists to establish unique profiles and measure how these characteristics impacted their learning. We asked the participants to report their gender, age, level of education, training area (considering the widely recognized division of ‘areas of knowledge’ in Brazil, namely ‘Exact sciences’, ‘Humanities’, and ‘Biological sciences’, and we added the ‘Interdisciplinary’ category to encompass participants with a more holistic background that might not fit neatly into those existing categories), the frequency of contact with nature, and if they were beekeepers (meliponists) or not. Contact with nature was defined as any contact with terrestrial, marine, or freshwater natural ecosystems, and protected areas (such as urban parks).

Knowledge of the Nature of Science: Our evaluation specifically focused on determining whether citizen scientists had an understanding of certain scientific project characteristics, mainly in natural sciences, such as the fact that they do not need to be complex or difficult and that they do not always need to rely on hypothesis testing. We considered a 5-point Likert scale (where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’).

Self-efficacy: Self-efficacy is an essential component of environmental citizenship, which depends on an individual’s beliefs about their capabilities to learn specific content, knowledge, and sufficient skills to bring positive change to their communities or themselves. Self-efficacy is sometimes referred to as “perceived competence” or “perceived behavioral control” [31]. We evaluated the participants’ perception of self-efficacy related to skills in bee biology, bee monitoring, meliponiculture, and science. To detect subtle changes in this dimension and increase the accuracy of our conclusions, we considered a 10-point Likert scale (where 1 is ‘not capable at all’ and 10 is ‘very much capable’).

Knowledge of Scientific Process: We evaluated whether citizen scientists understood scientific data collection and analysis processes, using the stingless bees’ flight activity monitoring protocol as a case study. We considered a 5-point Likert scale (where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’).

Knowledge of scientific content: We evaluated whether the participants understood theoretical content taught during the course, mainly content related to bees and meliponiculture. We considered a 5-point Likert scale (where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’).

Interest: Phillips et al. [30] defined interest as the degree to which an individual assigns personal relevance to a scientific or environmental topic or endeavor. It can also be considered a key precursor to deeper engagement in participatory decision-making processes in science [32]. We assessed the participants’ interests regarding bees, sustainability, science, and social interactions. We considered a 5-point Likert scale (where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’).

Values and priorities: Our evaluation specifically focused on how citizen scientists prioritized various dimensions of conservation, including environmental, social, and economic factors. We also sought to determine whether they were committed to contributing to the conservation of bees and whether they recognized the impact of bees on their overall quality of life. For this dimension, we proposed statements considering the construct of nature connectedness [33], and the theories related to personal norms [34], science denialism/trust in science [35,36], and prosocial/pro-environmental behavior [37,38]. We considered a 5-point Likert scale (where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’).

Motivation: Considering that motivation in citizen science is a complex construct and can be dynamic over time [39], we assessed the reasons leading the participants to engage in the course and to perform the proposed citizen science protocol (pre-questionnaire) and the reasons leading the participants to continue monitoring bees after the course’s (post-questionnaire). For this, we elaborated statements by taking into account the ideas proposed by Batson et al. [40], who identified four types of motivations for social participation toward common goals: egoism, altruism, collectivism, and principlism (see Table 1). The respondents could choose up to three given options.

Table 1. Aspects of the participants’ profiles and indicators of each dimension of learning evaluated in the pre- and post-questionnaires. The Likert scales are indicated for each learning dimension (1–5, where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’; or 1–10, where 1 is ‘not capable at all’ and 10 is ‘very much capable’). Those statements for which the responses were reversed for the analysis are indicated with an (R) right before them.

Profile
• Gender (Female, Male, Non-binary, I prefer not to answer) • Age (20–39 y/o, 40–59 y/o, 60–79 y/o) • Level of education (Basic education, Higher education–complete, Higher education–ongoing, graduate) • Area of knowledge–higher education only (Exact Sciences, Humanities, Biological Sciences, Interdisciplinary Sciences, no Higher Education) • Contact with nature (Frequently–Once a week or more, Sometimes–Between once a week and once a month or Rarely–Less than once a month) • Are you a Meliponist? (yes/no)
Knowledge of the Nature of Science (Likert Scale: 1–5)
For a project to be considered scientific, it must: • (R) Be complex • (R) Be difficult • Propose a way to analyze the data • Try to answer a question that is in society’s interest • (R) Have testable hypotheses
Self-Efficacy (Likert Scale: 1–10)
• If you were invited to participate in a bee monitoring project, how capable of helping that project do you think you would be? • How capable do you think you would be if you were asked to take care of a stingless bee colony (protect, feed)? • If you were asked to perform stingless bee colony management (such as capable transfers and multiplications), how capable of performing these tasks do you think you would be? • What do you think is your ability to identify a stingless bee species? • How capable do you think you are of performing stingless bee counting on the flight in a video? • How capable do you think you are of asking a scientific question for a research project?

Table 1. Cont.

Knowledge of Scientific Process (Likert Scale: 1–5)—Related to the Citizen Science Protocol Trained during the Course
• (R) Stingless bees collect resources evenly throughout the day • On cold and rainy days the external activity of bees decreases • (R) My presence close to the nest does not interfere with the bees' flight activity • (R) The time of year does not influence the flight activity of bees • (R) To monitor the bees' flight activity, I must feed them before • It is possible to monitor the flight activity of bees, both on cold and hot days • (R) To monitor the bee flight activity, I must choose the time of highest activity • (R) Only professional scientists should monitor the flight activity of stingless bees • Monitoring bee flight activity during a swarm can generate unreliable data • (R) Laboratory equipment is required to monitor the flight activity of stingless bees
Knowledge of Scientific Content (Likert Scale: 1–5)—Related to the Training Course
• Cultivate flowers is important for beekeeping • I should only feed the bees in times of scarcity of resources • I should only keep bees that occur in my region • (R) There is no problem transporting the nests over long distances • (R) Meliponiculture has low potential to be a sustainable activity
Interests (Likert Scale: 1–5)
• I like to study bees • I like to keep bees • I like science • I like to do scientific research • I like to interact with new people • I am interested in the protection of bee species • I am interested in the subject of "sustainability"
Values and Priorities (Likert Scale: 1–5)
• Bees contribute to my well-being (nature connectedness) • Bees contribute to my quality of life (nature connectedness) • I feel responsible for the conservation of bees (personal norms) • I would like to know how I can help conserve bees (personal norms) • Information about the death of bees is exaggerated (science denialism/trust in science) • A lot of money is spent on bee research (science denialism/trust in science) • We must conserve bees because they provide products that we use (nature connectedness) • It is more important to guarantee the income of poor people than to preserve bees (prosocial/pro-environmental behavior) • It is more important to build houses for those in need than to preserve bees (prosocial/pro-environmental behavior) • It is more important to produce food than to preserve natural habitats (prosocial/pro-environmental behavior)
Motivations (Up to Three Options Could be Chosen)—Types of Motivation Indicated between Parentheses, according to [40]
• Learn more about bees (egoism) • Contribute to scientific research on bees (altruism) • Meet people who deal with bees daily (egoism) • Meet researchers working with bees (egoism) • Helping in the conservation of bee species (principlism) • Contribute to the development of public policies (collectivism) • Do something relevant to society (collectivism) • Carry out a fun activity (egoism) • Learn to monitor bee nests (egoism) • Answering questions I have about bees and their nests (egoism) • Increase the productivity of my meliponary (egoism) • Increase my income (egoism)

2.4. Data Collection Instrument—Pre- and Post-Questionnaires

The questionnaire (Table 1) was developed and refined over three iterations of the Outreach Course in Meliponiculture and Citizen Science, conducted in the second half of 2020, as well as the first and second halves of 2021. Participants were different for each iteration, which allowed an iterative process of improvement in the data collection instrument based on the analysis of the results of these previous iterations of the course. All questions were designed with closed-ended formats, including multiple-choice and Likert scale responses (1–5, where 1 is ‘strongly disagree’ and 5 is ‘strongly agree’; or 1–10, where 1 is ‘not capable at all’ and 10 is ‘very much capable’). Only the results from the fourth iteration of the course were considered in the present study. To evaluate the internal consistency among groups of questions within the same learning dimensions, Cronbach’s α [41] was employed. The α coefficient was calculated by aggregating participants’ responses for each dimension before and after the course using the R package psych (Table 2). Although a Cronbach’s α of 0.60 is the minimum acceptable in most statistical references, there exists a large variation in the α value interpretation in science education research. For instance, low α values, such as 0.45, were labeled as “acceptable” or “sufficient” in previous studies [42]. Since constructs with few items usually show lower α values, we considered that accepting these values might be reasonable, as some of the learning dimensions assessed in our study exhibited few items (e.g., knowledge of the nature of science, α pretest = 0.52, with five items). We adopted a cut-off value of 0.50 according to Hinton et al. [43], who stated that α values between 0.50 and 0.70 indicated moderate reliability, while values below 0.50 indicated low reliability. Thus, the results of the knowledge of scientific content dimension must be interpreted cautiously since the α values indicated low reliability (pre = 0.35, post 0.40). Knowledge about the scientific process showed a low α in the pretest (0.44), but a reliable value in the post-test (0.64) (Taber 2018). All other Cronbach’s α values were classified as moderately reliable and very reliable. The dimensions with the highest values were self-efficacy (initial: 0.86; final: 0.83) and interest (initial: 0.81; final: 0.85). Despite attempts to regroup or remove questions, Cronbach’s α did not exhibit improvement for dimensions with low reliability. Hence, we decided to retain them as the final version of the questionnaire (Table 1) and explore potential modifications for future course editions.

Table 2. Cronbach’s α for each learning dimension in the pre- and post-questionnaires.

Learning Dimension	Cronbach’s α (Pre)	Cronbach’s α (Post)
Knowledge of the Nature of Science	0.52	0.62
Self-Efficacy	0.86	0.83
Knowledge of Scientific Process	0.44	0.64
Knowledge of Scientific Content	0.35	0.40
Interest	0.81	0.85
Values and priorities	0.56	0.57

Note: Alpha values ranged between 0 and 1, with higher values indicating higher reliability in each construct. In this study, alpha values between 0.50 and 0.70 were considered moderately reliable. Values above 0.70 were considered highly reliable, while values below 0.50 were considered with caution (see the methods section for details).

2.5. Statistical Analyses

For each learning dimension (Section 2.3 and Table 1), except for motivation, values, and priorities, we calculated the average scores for the group of statements, as we intended to assess shifts for each dimension rather than shifts in individual statements. We reversed respondents’ scores on reverse-coded statements before calculating the average scores and running the analysis (see which statements had the scores reversed in Table 1).

In order to investigate if there was an increase in the average scores following the course (which would indicate learning or a change in participants’ perceptions), and to ascertain if these changes were influenced by the participants’ profiles, we employed linear mixed-effects models. The process of model selection was used to validate our hypotheses. The average scores were fitted as the response variables, with time (pre- and

post-questionnaires) and their interaction with six profile variables as predictors (age, gender, level of education, area of knowledge, contact with nature, and if the person was a beekeeper). The participant's identity was included as a random factor to account for dependencies in data. All models were fitted using the R package *lmerTest* [44]. The dispersion was diagnosed by comparing the residuals of the fitted model to simulated residuals ($n = 10,000$ simulations), using the R package *DHARMA* [45]. Based on these simulations, we also inspected the presence of outliers, which were removed from our dataset, and the final sample sizes for the analysis of each dimension are shown in Table 3. The model selection was performed by deleting each interaction term and comparing the full model (with interactions) to the reduced one (without interactions) with an F-test using Satterthwaite's method. Starting with a full model with all predictors (time and the interaction of time with the six profile variables), each interaction was removed and significant interactions were kept in the model. As the aim of the analysis was to assess whether profile variables influenced learning (not the individual effects of profile variables on the performance of participants at any given time), only interactions with time were removed during the model selection. This procedure was repeated until the best model was reached.

For values and priorities, we analyzed the statements related to the constructs and theories that underpinned each one in detail, so we could understand our participants better. We considered that it was very likely that the participants presented a high degree of nature connectedness, strong personal norms, a neutral position on statements that conflicted with prosocial and pro-environmental behaviors, and moderate to high levels of trust in science.

Regarding the motivation dimension, the number of participants who selected each given option was counted, with n_i being the number of participants who chose a given option in the pre-questionnaire and n_f being the number of participants who chose that same option in the post-questionnaire. The percentage increase or decrease in motivations was calculated from the subtraction of n_i from n_f and dividing this value by n_i , followed by multiplying the result by 100.

Table 3. Best models describing each learning dimension, including the number of respondents (N), interactions between fixed factors, degree of freedom (df), F-test values (F) and p -values for the effect of removing each interaction. 'Time' means the periods before and after the training course and 'beekeeper' means if the participant was a meliponist or not. Bold values denote statistical significance at the $p < 0.05$ level.

Learning Dimension	N	Interaction	df	F	p -Value
Knowledge of the Nature of Science	853	Time: Level of education	3	2.75	0.04
		Time: Area of knowledge	4	2.66	0.03
Self-efficacy	857	Time: Gender	3	4.32	<0.01
		Time: Beekeeper	1	19.60	<0.001
Knowledge of Scientific Process	855	Time: Area of knowledge	4	3.08	0.01
		Time: Beekeeper	1	7.96	<0.01
Knowledge of Scientific Content	855	Time: Beekeeper	1	39.07	<0.001
Interest	836	Time: Beekeeper	1	8.26	<0.01

3. Results

3.1. General Profile

Most of the participants had achieved or were pursuing higher education (43.71%), predominantly in the humanities (28.50%) or biological sciences (27.43%), and most of them held graduate degrees (38.80%). Approximately two-thirds were male (65.75%), and the majority (65.15%) frequently engaged with nature (once a week or more). Over half of the

participants were meliponists (52.34%), and most participants (46.23%) were between the ages of 40 and 59 (Table 4).

Table 4. Participants' general profiles (self-declared demographic aspects of the course participants shown in percentages by group; $n = 857$).

Gender		Age		Level of Education	
Female	34.01%	20 to 39	38.32%	Basic Education	17.49%
Male	65.75%	40 to 59	46.23%	Higher Education (Complete)	30.42%
Non-binary	0.12%	60 to 79	15.45%	Higher Education (Ongoing)	13.29%
I prefer not to answer	0.12%			Graduate	38.80%
Training (Area of Knowledge) (Higher Education)		Beekeeper		Contact with Nature	
Exact Sciences	17.72%	Meliponist	52.34%	Rarely	9.58%
Humanities	28.50%	Non-meliponist	47.66%	Occasionally	25.27%
Biological Sciences	27.43%			Frequently	65.15%
Interdisciplinary Sciences	7.31%				
No Higher Education	19.28%				

3.2. Knowledge of the Nature of Science

Knowledge about the nature of science was affected by the time of the questionnaire application and its interaction with the level of education and the training area of knowledge (Tables 3 and 5). Regarding the level of education—as an individual factor independent of time—average scores were higher for graduate participants when compared to participants with basic education (Figure 1b). Even though positive learning was observed for all educational levels, participants with basic education showed higher learning than those with higher education (3.4 times higher, according to the model predictions, Figure 1a). Training regarding the area of knowledge as an individual factor also affected the scores (Figure 1b), with participants from exact sciences and humanities showing lower average scores. Positive learning was observed for the participants in all areas of knowledge, with those with interdisciplinary science backgrounds exhibiting higher learning when compared to those from biological science backgrounds (1.8 times higher, according to model predictions).

Table 5. Parameter estimates for the best model describing the respondents' average scores for the 'Knowledge of the Nature of Science' dimension. Time estimates are given with the "pre-questionnaire" as the comparison level, estimates for the level of education are given with "basic education" as a comparison level, and estimates for the area of knowledge are given with "biological sciences" as the comparison level. Std. Error is the standard error, df denotes the degree of freedom computed using the Satterthwaite approximation, and p -values were calculated for t -tests. Values in bold indicate that the estimate values are significantly different from zero.

	Estimate	Std. Error	df	p -Value
(Intercept)	4.01816	0.13251	1407.32757	<0.0001
Time Post	0.49966	0.13921	845.00000	0.000351
Level of Education Higher Education (Ongoing)	0.19216	0.12232	1407.32757	0.116433
Level of Education Higher Education (Complete)	0.23282	0.13448	1407.32757	0.083611
Level of Education Graduate	0.33918	0.13322	1407.32757	0.011000
Area of Knowledge Exact Sciences	−0.14419	0.05900	1407.32755	0.014649
Area of Knowledge Humanities	−0.19050	0.05352	1407.32755	0.000384
Area of Knowledge Interdisciplinary Sciences	−0.14194	0.08096	1407.32755	0.079785
Area of Knowledge No Higher Education	−0.04127	0.12803	1407.32757	0.747244
Time Post: Level of Education Higher Education (Ongoing)	−0.36105	0.12851	845.00000	0.005076
Time Post: Level of Education Higher Education (Complete)	−0.38432	0.14127	845.00000	0.006655
Time Post: Level of Education Graduate	−0.36792	0.13995	845.00000	0.008722
Time Post: Area of Knowledge Exact Sciences	0.10865	0.06198	845.00000	0.079978
Time Post: Area of Knowledge Humanities	0.10769	0.05623	845.00000	0.055813
Time Post: Area of Knowledge Interdisciplinary Sciences	0.17176	0.08506	845.00000	0.043760
Time Post: Area of Knowledge No Higher Education	−0.20055	0.13450	845.00000	0.136330

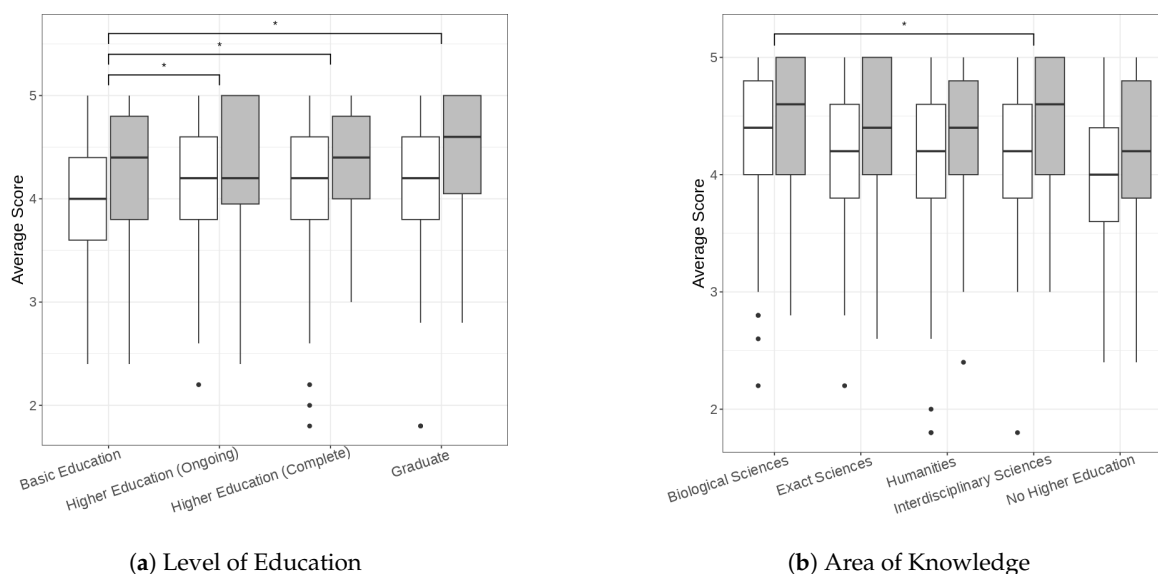


Figure 1. Box plot of the respondents' average scores for the "Knowledge of the Nature of Science" dimension in the pre-questionnaires (white bars) and post-questionnaires (gray bars), considering the (a) level of education and (b) area of knowledge. Asterisks represent significant differences, considering interactions between the time of the questionnaire application and profile variables (for instance, participants with basic education exhibited higher learning than other participant categories, while participants from interdisciplinary sciences exhibited higher learning than those from biological sciences). Black circles represent outliers. The effects of the time and profile variables as individual factors are shown in Table 5.

3.3. Self-Efficacy

Self-efficacy was affected by the time of the questionnaire application, its interaction with gender, and if the participant was a meliponist or not (Tables 3 and 6). Regarding gender and being a meliponist as individual factors, higher scores were observed for males and meliponists when compared to females and non-meliponists, respectively. All groups exhibited an increase in their average scores in the post-questionnaires, revealing an increase in their perception of self-efficacy. However, females showed higher increases than males (1.27 times higher, according to model predictions, Figure 2a) and non-meliponist showed higher increases than meliponists (1.31 times higher, according to model predictions, Figure 2b).

Table 6. Parameter estimates for the best model describing the respondents' average scores for the "Self-Efficacy" dimension. Time estimates are given with "pre-questionnaire" as the comparison level, estimates for the level of gender are given with "female" as a comparison level and estimates for beekeepers are given with "non-meliponist" as a comparison level. Std. Error is the standard error, df denotes the degree of freedom computed using the Satterthwaite approximation, and *p*-values were calculated for *t*-tests. Values in bold indicate that the estimated values are significantly different from zero.

	Estimate	Std. Error	df	<i>p</i> -Value
(Intercept)	5.85224	0.09807	1429.12235	<0.001
Time Post	2.15555	0.10392	852.00000	<0.001
Gender Male	0.46731	0.11424	1429.12235	<0.001
Gender Non-binary	1.31443	1.54826	1429.12235	0.40
Gender I Prefer not to say	−1.32321	1.54933	1429.12235	0.39
Beekeeper Meliponist	0.80430	0.10869	1429.12235	<0.001
Time Post: Gender Male	−0.41445	0.12106	852.00000	<0.001
Time Post: Gender Non-binary	−0.98889	1.64062	852.00000	0.546
Time Post: Gender I Prefer not to answer	1.35440	1.64176	852.00000	0.409
Time Post: Beekeeper Meliponist	−0.50995	0.11517	852.00000	<0.001

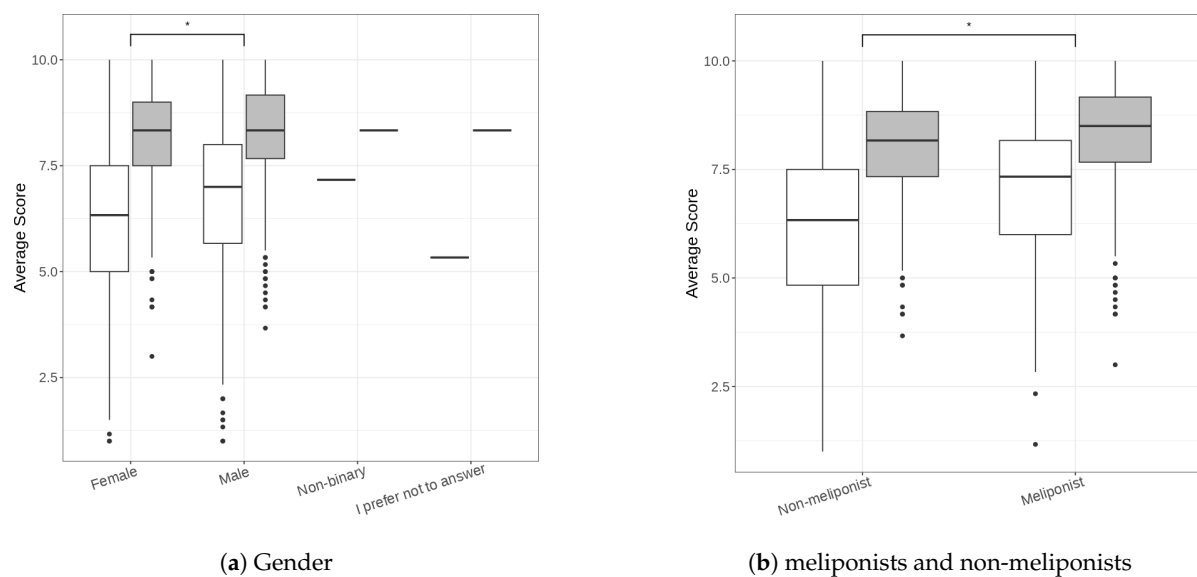


Figure 2. Box plot of the respondents' average scores for the "Self-Efficacy" dimension in the pre- (white bars) and post- (gray bars) questionnaires, considering (a) gender and (b) if the respondent was a meliponist or not. Asterisks represent significant differences, considering interactions between the time of the questionnaire application and profile variables (for instance, females and non-meliponists exhibited higher learning than males and meliponists, respectively). Black circles represent outliers. The time and profile variables as individual factors are shown in Table 6.

3.4. Knowledge of the Scientific Process

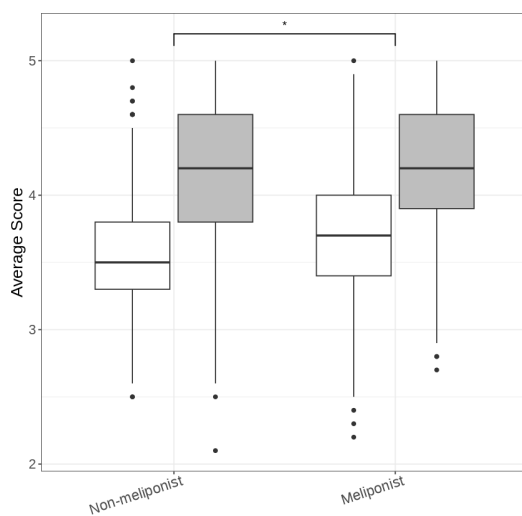
Knowledge of the scientific process was affected by the time of the questionnaire application, its interaction with training the area of knowledge, and if the participant was a meliponist or not (Tables 3 and 7). Regarding training in the area of knowledge as an individual factor independent of time, participants from the exact sciences, humanities, and with no higher education showed lower average scores when compared to participants from biological sciences. In addition, meliponists showed higher scores than non-meliponists when being a meliponist as an individual factor was analyzed. All groups increased their scores after the course, suggesting positive learning. However, non-meliponists showed higher learning than meliponists (1.19 times higher, according to model predictions, Figure 3a) and participants from the exact sciences showed higher learning than those from biological sciences (1.31 times higher, according to model predictions, Figure 3b).

Table 7. Parameter estimates for the best model describing the respondents' average scores for the 'Knowledge of the Scientific Process' dimension. Time estimates are given with the "pre-questionnaire" as the comparison level, estimates for the level of education are given with "basic education" as the comparison level, estimates for the area of knowledge are given with "biological sciences" as the comparison level, and estimates for the beekeeper are given with "non-meliponist" as the comparison level. Std. Error is the standard error, df denotes the degree of freedom computed using the Satterthwaite approximation, and *p*-values were calculated for *t*-tests. Values in bold indicate that the estimated values are significantly different from zero.

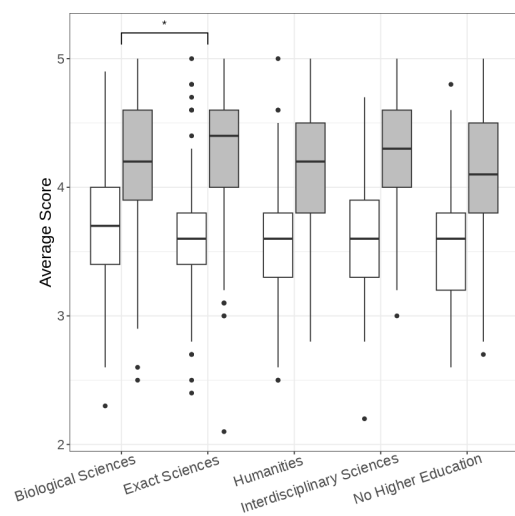
	Estimate	Std. Error	df	<i>p</i> -Value
(Intercept)	3.63841	0.03361	1476.11446	<0.001
Time Post	0.56258	0.03719	849.00000	<0.001
Area of Knowledge Exact Sciences	−0.10642	0.04806	1476.11446	<0.01
Area of Knowledge Humanities	−0.12775	0.04275	1476.11446	<0.001

Table 7. Cont.

	Estimate	Std. Error	df	p-Value
Area Of Knowledge Interdisciplinary Sciences	−0.08810	0.06604	1476.11446	0.182405
Area Of Knowledge No Higher Education	−0.18721	0.04821	1476.11446	<0.001
Beekeeper Meliponist	0.15108	0.03216	1476.11446	<0.001
Time Post: Area of Knowledge Exact Sciences	0.16424	0.05318	849.00000	<0.001
Time Post: Area of Knowledge Humanities	0.01938	0.04730	849.00000	0.682199
Time Post: Area Of Knowledge Interdisciplinary Sciences	0.12808	0.07308	849.00000	0.080016
Time Post: Area Of Knowledge No Higher Education	0.03894	0.05335	849.00000	0.465589
Time Post: Beekeeper Meliponist	−0.10042	0.03559	849.00000	<0.001



(a) meliponists and non-meliponists



(b) Area of Knowledge (Higher Education)

Figure 3. Box plot of the respondents' average scores for the "Knowledge of the Scientific Process" dimension in the pre- (white bars) and post- (gray bars) questionnaires, considering (a) if the respondent was a meliponist or not; and (b) the area of knowledge. Asterisks represent significant differences, considering interactions between the time of the questionnaire application and profile variables (for instance, non-meliponists and participants from the exact sciences showed higher learning than meliponists and those from biological sciences, respectively). Black circles represent outliers. The time and profile variables as individual factors are shown in Table 7.

3.5. Knowledge of Scientific Content

Knowledge of scientific content was affected by time and its interaction with being a beekeeper (Table 8). When considering being a meliponist as an individual factor that is independent of time, meliponists showed higher average scores than non-meliponists. All groups increased their scores after the course, suggesting positive learning. However, non-meliponist participants showed higher learning than meliponists (2.41 times higher, according to model predictions; see Figure 4a).

3.6. Interest

Interest was affected by time and its interaction with being a beekeeper (Table 9). When considering being a meliponist as an individual factor independent of time, meliponists showed higher scores than non-meliponists. All groups exhibited an increase in their scores after the course, suggesting an increase in interest along the course. However, non-meliponist participants showed a higher increase in interest than the meliponists (4.5 times higher, according to model predictions; see Figure 4b).

Table 8. Parameter estimates for the best model describing the respondents’ average scores for the ‘Knowledge of Scientific Content’ dimension. Time estimates are given with the “pre-questionnaire” as the comparison level. Std. estimates for beekeeper are given with “non-meliponist” as the comparison level. Std. Error is the standard error, df denotes the degree of freedom computed using the Satterthwaite approximation, and *p*-values were calculated for *t*-tests. Values in bold indicate that the estimated values are significantly different from zero.

	Estimate	Std. Error	df	<i>p</i> -Value
(Intercept)	3.99951	0.02531	1483.22777	<0.001
Time Post	0.41460	0.02801	853.00000	<0.001
Beekeeper Meliponist	0.30229	0.03512	1483.22777	<0.001
Time Post: Beekeeper Meliponist	−0.24298	0.03887	853.00000	<0.001

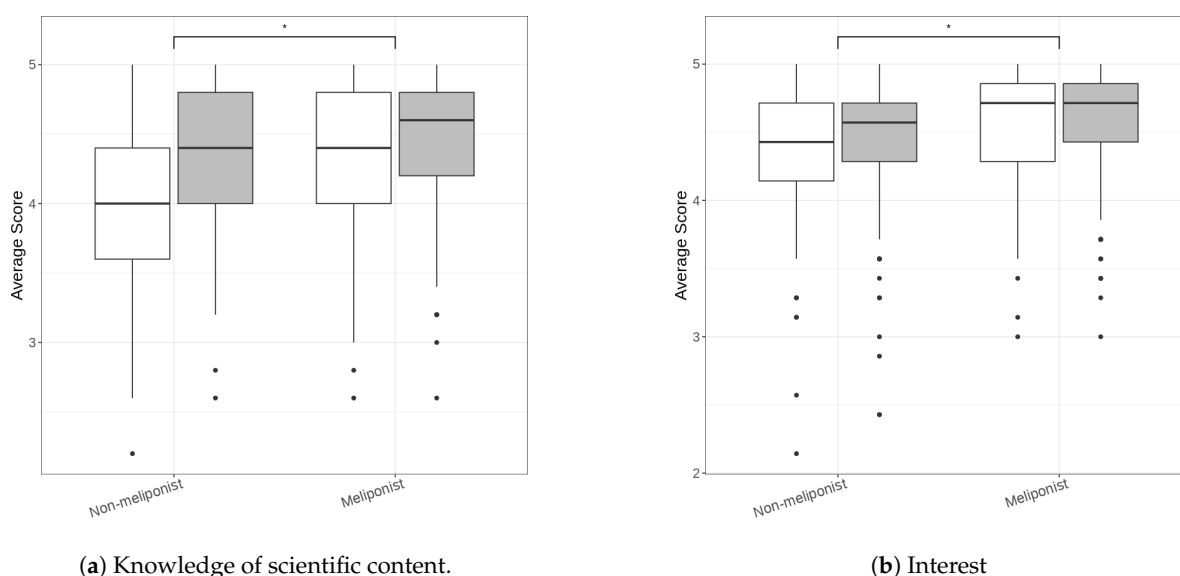


Figure 4. Box plot of the respondents’ average scores for non-meliponists and meliponists, considering the (a) “Knowledge of Scientific Content” and (b) “Interest” dimensions in the pre- (white bars) and post- (gray bars) questionnaires. Asterisks represent significant differences, considering interactions between the time of the questionnaire application and being a meliponist (for instance, non-meliponists showed higher learning than meliponists in both dimensions). Black circles represent outliers. The times and the profile variables as individual factors are shown in Tables 8 and 9.

Table 9. Parameter estimates for the best model describing the respondents’ average scores for the ‘Interest’ dimension. Time estimates are given with the “pre-questionnaire” as the comparison level, and Std. estimates for the beekeeper are given with “non-meliponist” as the comparison level. Std. Error is the standard error, df denotes the degree of freedom computed using the Satterthwaite approximation, and *p*-values were calculated for *t*-tests. Values in bold indicate that the estimated values are significantly different from zero.

	Estimate	Std. Error	df	<i>p</i> -Value
(Intercept)	4.39444	0.01961	1163.30395	<0.001
Time Post	0.08621	0.01621	834.00002	<0.001
Beekeeper Meliponist	0.17666	0.02735	1163.30395	<0.001
Time Post: Beekeeper Meliponist	−0.06494	0.02260	834.00002	<0.001

3.7. Values and Priorities

Participants strongly agreed that bees contributed to their well-being (average scores in the pre-questionnaire = 4.75 and in the post-questionnaire = 4.76) and their quality of life (pre = 4.77 and post = 4.79), and they felt responsible (pre = 4.65 and post = 4.72) and

wanted to know how they could help conserve bees (pre = 4.78 and post = 4.65). They disagreed with the statements that affirmed that too much money was spent on research about bees (pre = 2.12 and post = 2.01) and that information about the death of bees was exaggerated (pre = 2.10 and post = 2.03). They also disagreed with the statement about conserving bees because they provide us with products (pre = 1.79 and post = 1.67). They disagreed that it was more important to guarantee the income of poor people (pre = 1.57 and post = 1.48) or to build houses for those in need (pre = 1.53 and post = 1.46) than to preserve bees. Finally, they neither agreed nor disagreed with the statement that it was more important to produce food than to preserve natural habitats (pre = 3.37 and post = 3.41).

3.8. Motivation

Regarding the motivation dimension, the top three options chosen in both questionnaires were as follows: Aiding in the conservation of bee species (principlism, $n_i = 700$ and $n_f = 561$), learning more about bees (egoism, $n_i = 651$ and $n_f = 516$), and contributing to scientific research on bees (altruism, $n_i = 443$ and $n_f = 396$). Only three options, the “egoism” motivation types, presented a higher number of responses in the post-questionnaire (Table 10). After the training process, participants were more motivated to (i) Answer questions about bees and their nests (46.51% growth); (ii) carry out a fun activity (22.73% growth); and (iii) increase the meliponary productivity (12.50% growth). The other alternatives showed a decrease, with a reduction of 100% for the option “Learn to monitor bee nests”.

Table 10. Number of participants who chose each motivation option in the pre- and post-questionnaires. n_i is the number of participants who chose a given option in the pre-questionnaire and n_f is the number of participants who chose that same option in the post-questionnaire. Relative % is the percentage increase or decrease in motivation relative to the pre-questionnaire.

Selected Answer	n_i	n_f	Relative %
Learn more about bees	651	516	−20.74%
Contribute to scientific research on bees	443	396	−10.61%
Meet people who deal with bees daily	76	60	−21.05%
Meet researchers working on bees	108	78	−27.78%
Helping in the conservation of bee species	700	561	−19.86%
Contribute to the development of public policies	148	109	−26.35%
Do something relevant to society	192	133	−30.73%
Carry out a fun activity	22	27	22.73%
Learn to monitor bee nests	85	0	−100%
Answering questions I have about bees and their nests	43	63	46.51%
Increase the meliponary productivity	48	54	12.50%
Increase my income	30	24	−20%

4. Discussion

The results of this study provide valuable insights into the factors that influence the learning outcomes of participants during the training course of the #cidadãoasf citizen science project. The data suggest that participant profile parameters, such as gender, level of education, training area of knowledge, and being a meliponist can indeed impact specific learning outcomes.

It is important to underscore that the questionnaire utilized in the current study was not derived from pre-existing and previously validated instruments but was instead crafted explicitly for the context of the training process under evaluation. While we employed validation strategies, including an iterative process and the assessment of internal consistency through the calculation of Cronbach’s α [46], there remains potential for enhancement. Consequently, we advocate for subsequent studies to be conducted to refine this instrument further and create and validate novel questionnaires for the assessment of training processes within the realm of citizen science.

4.1. General Profile

The profiles of course participants do not reflect the average characteristics found in the Brazilian population. Most of the participants had achieved or were pursuing higher education (43.71%), while the actual percentage of the Brazilian population in these conditions was 23.3% [47]. Additionally, two-thirds were male and most were aged between 40 and 59 years; Brazil has a female majority (51.1%) and most of the population is between 30 and 49 years old (30.1%) [48].

4.2. Knowledge of the Nature of Science

Few citizen science projects have attempted to study their participants' learning of the nature of science [30,49], which makes reflections on our results somewhat limited. Our study shows that the level of education influenced the scores obtained and the learning only in this dimension, which is somewhat inconsistent with previous research that positively correlated educational levels with learning and knowledge acquisition in general [50–52].

We observed learning (i.e., an increase in the scores from the pre- to the post-questionnaires) for participants of all levels of education and different training areas of knowledge. However, we found that participants with higher education levels initially scored higher in this dimension, but those with basic education showed greater learning, which may suggest that the course content was more novel or impactful for those with less formal education, filling gaps in their knowledge that were not addressed in their previous education. It is also noteworthy that participants from the exact sciences and humanities showed lower average scores. This could be due to a variety of factors, such as differences in prior exposure to content related to the knowledge of the nature of science or even differences in the way these individuals approach learning. In a similar study, although not assessing learning related to the nature of science, Golumbic et al. [53] found that citizen scientists with higher levels of education achieved higher average scores in an online questionnaire involving air quality data, followed by interpretation questions regarding the 'Sensing the Air' project. In this same study, the authors found that more experienced citizen scientists, even those with lower levels of formal education, also achieved high scores, suggesting that while formal scientific education is important, the experience obtained in participating in a citizen science project may improve the scientific literacy of participants. We did not assess participants' learning, taking into account their level of experience in contributing to our project, but future studies could test for this factor.

4.3. Self-Efficacy

Our findings showed an interaction between time and both gender and being a meliponist, affecting average scores in the self-efficacy dimension. The fact that males and meliponists had higher scores may reflect societal or cultural factors that led these groups to have greater confidence in their abilities. However, the greater increase in self-efficacy among females and non-meliponists suggested that the course was particularly effective at boosting confidence among these groups. The results of other studies evidence that the perception of self-efficacy can increase [54] or decrease [22] after participation in a citizen science project, with the latter possibly due to participants' increased awareness of their lack of knowledge. Additionally, previous studies have shown that the perception of self-efficacy is influenced by gender, with males reporting higher self-efficacy in science-related tasks [55,56] or showing significantly higher levels of perception of self-efficacy in mathematics, computers, and social sciences [57] than females. Considering that the participants of the training course were mainly males (65.75%), it is possible that females did not feel confident in their abilities to participate. Thus, future editions of the course could consider gender equity actions to encourage female participation.

The higher self-efficacy average scores for meliponists were expected because of their previous experiences that were (self-declared in the pre-questionnaires) in subjects related to bees, meliponiculture, and their contribution to scientific research. According to Steyn and Mynhardt [58], self-referenced information can profoundly influence perceptions

of self-efficacy, so meliponists likely feel more confident based on their self-evaluation about their ability to contribute to science. Our findings also evidenced a higher increase in the scores of non-meliponists, indicating that the training course achieved its expected objective of making the participants with no or little previous experience feel more confident in contributing to a scientific project.

According to Crall et al. [13], self-efficacy is critical in carrying out project activities and empowering individuals to undertake future environmental stewardship actions. Based on our findings, when evaluating the self-efficacy of citizen scientists, it's important to consider individual profile aspects. This approach forms a foundation for proposing strategies that promote diversity and equity in citizen science projects.

4.4. Knowledge of Scientific Process

The questions answered by the participants of the training course in this learning dimension were mainly related to their understanding of the #cidadãoflight activity monitoring protocol, which was taught in detail and executed by them during the training course. The higher average scores obtained by the participants from the biological sciences were expected because we considered aspects in the questionnaires that were related to ecological factors (e.g., temporal dynamics in resource collection or the flight activity of bees) or sampling procedures (e.g., randomization in data collection) that were important for the application of the protocol, and that would probably be known to people with training in this area. The higher learning presented by non-meliponists and participants from exact sciences suggest that the course was effective at conveying this knowledge (e.g., how to formulate research questions, hypothesis testing, monitoring protocol steps, data visualization, and analysis) to those without prior experience. Those participants who were meliponists already had some knowledge about the scientific inquiry process, since many of them had already collaborated with scientific research, as reported in the pre-questionnaire. Our results corroborate those found in other studies that showed an increase in the understanding of the scientific process by participants in citizen science projects [12,59], although this is not always the case [17]. Also, the increase in Cronbach's α in the post-questionnaire indicates that the participants' answers were more concordant with each other after the course, indicating that the participants, in general, understood how to execute the proposed protocol.

4.5. Knowledge of Scientific Content

For this learning dimension, meliponists showed higher average scores than non-meliponists, which was somewhat expected, given that the questions primarily focused on bees and meliponiculture. The greater learning outcomes observed among non-meliponists emphasize the significance of training initiatives aimed at enhancing the development of meliponiculture, which aligns with the findings of Barbiéri and Francoy [27]. In addition, our findings are in accordance with other studies that emphasize the importance of training and participation in citizen science projects for a better understanding of scientific topics (e.g., [1,17,60–62]), or even for a better use of scientific terminology and vocabulary related to a specific scientific topic [63]. However, as mentioned in the methodology section, the values of Cronbach's α obtained in the pre- (0.35) and post-questionnaires (0.40) indicate that the results in this particular learning dimension must be considered with care.

4.6. Interest

The average scores of this dimension increased in the post-questionnaire. The only profile variable affecting interest was whether the participant was a meliponist or not. Those who were meliponists practically did not change their interest (which was already high in the pre-questionnaire) after participating in the course. The higher increase in interest for non-meliponists indicates that the training course successfully reached this target group.

According to Vohland et al. [1], interests are more frequently assessed as previous factors leading to participation; moreover, Phillips et al. [30] state that an audience's pre-existing interests in specific topics may not change significantly through participation. In fact, few studies have assessed participants' interests after participating in a citizen science training course or initiative; for example, Price and Lee [22] reported an increased interest in science among citizen sky observers. Our results also showed that interests are dynamic over time. As there is a possibility that interests are related to other individual learning outcomes, we consider it important that other studies be carried out with the aim of assessing the interests of citizen scientists, and correlating them, for example, with motivations, engagement, and behaviors.

4.7. Values and Priorities

It was noticeable that the participants, in general, showed high levels of nature connectedness both before and after the training course, considering bees as an important element for their well-being and quality of life. Additionally, they showed strong personal norms, stating that they felt responsible for the conservation of bees, and they wanted to know how to help in conserving these organisms. Understanding personal norms is important because they directly predict pro-environmental behavioral intentions. Indeed, it was noticeable that the participants prioritized pro-environmental behavior over prosocial behavior when they considered that preserving bees was more important than providing income or housing for poor people. This was not expected as previous research suggests that individuals prioritize prosocial over pro-environmental motives whenever these motives conflict [64]. However, the high levels of nature connectedness and strong personal norms may be correlated to and explain the observed high levels of pro-environmental behavior, as also observed by Martin et al. [65] and Schultz et al. [66]. The statement "It is more important to produce food than to preserve natural habitats" showed an average score of approximately 3.4, which can be considered as "neutral". This statement was different from the other two, where we analyzed prosocial/pro-environmental behaviors, since we did not mention for whom the food was going to be destined, and perhaps the participants felt they were part of those individuals who would benefit from the production of food too.

Finally, the analysis of our findings demonstrates that the participants showed high levels of trust in science; this level of trust increased after the training course since we observed a decrease in the average scores of the statement that affirmed too much money was spent on bee research and that information about the death of bees was exaggerated. The fact that the average scores were between 2.01 and 2.12 also indicated that participants were careful and indicated not to blindly trust science, approaching what Hendriks et al. [36] called epistemic trust (the assumption that one is dependent on the knowledge of others who are more knowledgeable, but also vigilant toward the risk of being misinformed).

We consider our results in this dimension very insightful regarding the profiles of those who engage in socio-environmental citizen science initiatives. These are, in our case, people with high levels of nature connectedness, strong personal norms, pro-environmental behavior(al intentions), and high levels of trust in science.

4.8. Motivation

Although participants in the same citizen science project share certain motivations, it is important not to treat them as homogeneous. While a citizen scientist may engage in a project for various reasons, these motivations are dynamic and can change over time [67], as shown by our results. Since the post-questionnaire was answered after completing the course and running the protocol, it was anticipated that there could be changes in the factors that drive participation in the project.

Our findings demonstrate that the three main motivations of the participants of the training course were to learn (egoism), and to help the conservation (principlism) and production of scientific knowledge of bees (altruism). In the work of West et al. [68], who ran a hierarchical cluster analysis to group 613 environmental citizen scientists in Great

Britain by the types of motivations held, a cluster of people with egoism motivations (to learn something or further one's career) and value motivations (concern for others or the environment) was obtained. This cluster consisted of a higher proportion of some commonly underrepresented groups than the overall sample, including younger people, people from minority ethnic groups, and people in lower socioeconomic groups, which can, to some extent, be compared with the characteristics of the participants of the present study. Additionally, according to Rotman et al. [69], long-term participation in citizen science projects includes both self-directed (egoism) and collaborative motivations, indicating that our findings can be promising for the continued engagement of course participants in the #cidadãasf project.

The increase in participants' motivation, after the course, to answer research questions about bees and nests and to improve meliponary productivity, suggests that the course enabled the participants, many of whom were beekeepers, to formulate research questions of their own interests, aiming at better management of their meliponary activity over time. As the course consisted of a module focused on the management of meliponaries and another focused on the aspects of scientific research on bees and meliponaries and citizen science, we believe that the intended learning objectives of these modules were incorporated into the motivations of the participants.

Another option that showed an increase in relative percentage was "Carry out a fun activity". Although this option was chosen by a small number of participants ($n_i = 22$ and $n_f = 27$), by corroborating other studies in which this factor of the "egoism" type was not the most relevant to drive participation (e.g., [70,71]), our results indicate that some participants of the training course felt that monitoring, even with the demands for rigor in data collection, could be a leisure activity. We consider that the increase in the relative percentage of this option can be indicative of a further increase in engagement, as stated by Cox et al. [72].

Finally, we can make some speculations about the options that have shown a decrease. For example, the 100% decrease in the option "Learn to monitor bee nests" may be a sign that the participants felt confident in applying the monitoring protocol that was presented during the training course. The relative percentages of other items in the questionnaire may have shown a decrease due to similar reasons; since the participants had contact with researchers who worked on bees and with other people who worked with bees on a daily basis, they had access to knowledge about bees and meliponiculture, and contributed to scientific research on bees.

5. Conclusions

Citizen science projects and their corresponding training processes harbor immense potential to promote learning among a broad spectrum of participants, inclusive of diverse backgrounds and educational levels. Nevertheless, it is crucial for project planners to discern which variables relating to the participants' profiles may significantly impact the learning outcomes of their projects. This study's findings indicate that gender, educational background, level of education, and being a meliponist potentially have significant implications for specific learning outcomes in our citizen science initiative (#cidadãasf).

The meliponiculture and citizen science outreach training course successfully facilitated learning across seven proposed learning dimensions. Our evaluation of the influence of citizen scientists' profiles on learning outcomes revealed that certain course participant characteristics impacted their learning (e.g., training area of knowledge, level of education, and prior experience in meliponiculture). Despite this, all groups derived learning benefits from their course participation. This assessment offered insight into the subsequent steps and future training courses for the #cidadãasf citizen science project.

Considering that citizen science projects that align with volunteer interests and motivations can lead to better recruitment and retention, our findings are important in regard to detecting how motivations change over time and how interests can be different depending on the profiles of participants (in our case, interests were different for meliponists and

non-meliponists). Furthermore, our results show that a citizen science initiative focused on stingless bees can enhance participants' knowledge and practical skills, and contribute to scientific literacy and environmental awareness.

Finally, our study's findings could be beneficial to other citizen science projects, advocating for the evaluation of volunteer profiles to guide improvements in a project's quality. Possibly, the variables considered here are impactful in other projects as well; therefore, we recommend that they be considered during the planning and execution phases of citizen science projects. Specific considerations may include (1) the development of educational materials and processes that address issues of interest to particular groups of citizen scientists; (2) iteration training that emphasizes the complexity of the environmental issues under investigation, highlighting the importance of balancing social and environmental dimensions; (3) tailoring the language of a project's scientific communication and dissemination materials to the target audience's level of understanding; (4) involving citizen scientists in stages of the scientific process that align with their demonstrated skills; and (5) gradually increasing the difficulty of tasks assigned to citizen scientists as they show learning progress and gain confidence in performing the steps of the data collection protocol. By taking these factors into account, citizen science projects can more adequately achieve the goals desired by the coordinators for the chosen target audience.

Supplementary Materials: The following are available at <https://www.mdpi.com/article/10.3390/su151813545/s1>.

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