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Pilot test and validation of a teaching-learning sequence containing a citizen science protocol for phenological observation of trees

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ABSTRACT

Citizen science involves public participation in science, usually in projects containing protocols with a scientific question and data collection steps. These protocols need to be assessed and improved through pilot testing. The present work aims to validate an investigative teaching-learning sequence, which covers a school citizen science protocol, of phenological observation of trees, suitable for high school students. To this end, a pilot test of the sequence was carried out. The results obtained highlighted the need for changes in the citizen science protocol and some classes of the sequence. Among the changes, the following stand out: 1. inclusion of a more detailed training stage for data collection by students; 2. restructuring of the data collection form to make it clearer and more objective and 3. inclusion of the project in an online citizen science platform.

KEYWORDS: Life cycle of angiosperms. Data collection form. Training of citizen scientists.

1 INTRODUCTION

The term citizen science can be defined as scientific work carried out jointly by professional scientists and other sectors of society to promote science, foster a scientific mindset, and encourage democratic engagement in science, helping society to deal rationally with complex modern problems (Ceccaroni; Bowser; Brenton, 2017).

Citizen science projects use protocols and are guided by a scientific question, which requires the collection, analysis, and interpretation of data in order to be studied. In contributory and collaborative projects (Shirk *et al*., 2012), protocols are created by scientists and specify why, when, where, and how these data should be collected, and must be easy to implement, clearly and directly presented, and engaging for participants (Bonney *et al.,* 2009). For this to occur, it is essential that these protocols be validated through pilot testing, as is the case with any scientific research protocol. In these tests, efficiency, adequacy, usefulness, and clarity for the target audience are generally assessed, as well as the language used and how the audience perceives them, thus allowing necessary changes to be incorporated (Phillips *et al*., 2014). Since protocol testing allows for the guidance and improvement of procedures carried out by participants—who often have no prior experience in scientific research—it is expected that higher-quality data will be generated by citizen scientists when validated protocols are implemented, which is critical for any project (Bonney *et al.*, 2009; Lewandowski; Specht, 2015).

Recently, there has been an increase in the number of citizen science projects developed in schools, as they bring numerous benefits to students, especially contact with practical experiences in scientific investigation, critical thinking, and problem-solving (Shah; Martinez, 2016). In schools, citizen science protocols can be developed within teaching sequences on specific curricular content, following certain specifications (Shah and Martinez, 2016): 1. Scientific questions should be simple and appropriate to students' abilities to ensure they can successfully follow the methodology. 2. Project activities should not be excessive to avoid demotivation. 3. Prior guidance in data collection is essential to avoid bias and ensure the quality of results. 4. Learning objectives should be prioritized without compromising project quality. 5. Student participation in all stages of the project is important to maximize learning.

To ensure that these specifications and the principles of citizen science (Robinson *et al*., 2018) are met in such projects, it is essential that pilot testing takes place. Jardim and Marcelino (2021) point out that the validation of a teaching sequence is a fundamental activity and can significantly contribute to a more efficient teaching and learning process.

In this context, the objective of this study is to validate, through the evaluation of a pilot test application, an investigative teaching-learning sequence that includes an unprecedented school-based citizen science protocol for the phenological observation of trees, suitable for third-year high school students from a public school in São Paulo (SP).

2 METHODOLOGY

In this section, the methodological assumptions of the research, the context in which it took place, and the ethical issues involved will be presented, as well as how the research was conducted to obtain data and how these were analyzed.

2.1 Methodological assumptions

This research is characterized as mixed-methods (Knechtel, 2014) and was based on the assumptions of action research, in which the researcher acts as an intervener and agent of change through self-critical reflection on action (Francesconi; De Araújo, 2020). In the present study, the teacher of the classes (and first author of this work) was the research agent himself and acted in proposing changes to the teaching-learning sequence developed by him.

2.2 Research context and ethical issues

A teaching-learning sequence on the life cycle of angiosperms (plants that produce flowers and fruits) was applied, which included an unprecedented school-based citizen science protocol for the phenological observation of trees.

This sequence took place over 12 Biology classes, each lasting 45 minutes, between August and November 2021, involving 80 students from three third-year high school classes in a public state school in the northern region of the city of São Paulo (São Paulo State). In addition to the classrooms, the school courtyard and parking area were used for the development of activities.

The sequence aimed to assess students' learning regarding: 1. knowledge of content related to the life cycle of angiosperms, phenophases, and their relationships with the life cycle and pollination; 2. interest in science and botany; 3. perception of self-efficacy in science (how capable students feel when collaborating with scientific research); 4. scientific investigation skills, such as formulating hypotheses, collecting and organizing data, and drawing conclusions; and 5. behaviors and attitudes toward plants.

This research was approved by the Research Ethics Committee of the Federal University of ABC (CEP/UFABC) (CAEE No. 45817921.1.0000.5594). The legal guardians of underage students and students of legal age signed the Informed Consent Form (ICF), and underage students signed the Assent Form. These documents specified the risks and benefits of the research for participants.

2.3 Research procedures – Pilot test of the sequence

Lesson 1: It began with the administration of an initial individual questionnaire consisting of five open-ended and six closed-ended questions (Available at: http://tinyurl.com/ycs3xwwy), aimed at assessing interest in science and botany, perception of self-efficacy in science, and behaviors and attitudes toward plants. After submitting the completed questionnaires, the students were divided into groups, and the teacher explained the concept of hypothesis and provided some examples of how to structure them. Next, the guiding problem-question of the sequence was presented: "Joãozinho lives in a quiet neighborhood in the northern area. On the street behind his house, there is a very open square with beautiful silk floss trees (*Ceiba* sp.) that are full of large fruits that look like they are filled with cotton. Three times a week, Joãozinho plays soccer at night on a court in his neighborhood. The court was renovated more than a year ago and received large LED floodlights to make it brighter. Around the court, there are also silk floss trees, like those in the square, but these do not have fruits, only flowers. When he noticed this for the first time, he became intrigued, especially since the trees were of the same species and had the same age, as they were planted by the first residents of the neighborhood, so they should all have fruits. Joãozinho began to wonder: 'What could explain this difference?'" The teacher then asked each group to write a hypothesis explaining the difference between the trees in the two locations. The groups submitted their hypotheses at the end of the lesson.

Lesson 2: The teacher used slides to explain the concept of plant phenology, provide examples of the main phenophases of angiosperms, define what citizen science is, and present examples of citizen science project protocols, in order to contextualize the sequence for the students. Then, the scientific question of the protocol was presented, related to the problem-question: "Which possible factors influence the transition from the flowering phase to fruiting?" The teacher emphasized that the students would carry out monthly phenological observations, using a data collection form, of two trees at the school (an orchid tree – *Bauhinia variegata*, in the courtyard, and a sibipiruna – *Caesalpinia pluviosa*, in the parking lot), in order to identify the factor that might be responsible for flowers turning into fruits, which would be absent in the silk floss trees described in the problem-question. At the end of the lesson, the data collection form was presented (Available at: http://tinyurl.com/2chtztmt), and the teacher briefly explained how the groups should complete it during the observations.

Lessons 3, 4, 5, and 6: These corresponded to the monthly phenological observations of the trees. In each observation, the groups completed the data collection form with information about the location (date/time/temperature, weather conditions, wind intensity, presence of animals, and human interference in the surroundings) and indicated the predominant phenophase (or transition) in each tree (options: foliage – leaves only; between foliage and flowering – flower buds; flowering – open flowers; between flowering and fruiting – fruits appear, flowers persist; fruiting – fruits only, most mature). In addition, they took photographs using their own mobile phones of each tree and sent them to the teacher.

Lesson 7: It began with the presentation of the image (Available at: http://tinyurl.com/mtws5c2v) contained in the initial questionnaire, and students were asked to perform the same exercise of describing it. Then, images of animals and plants were presented, and students were asked to name them. Based on the responses, the concept of plant blindness and its characteristics was introduced, which led to discussions about how plants often go unnoticed by us and their importance in different contexts.

Lesson 8: The teacher presented the life cycle of angiosperms through a video produced by him and adapted from the documentary "Flowers: The Secret Life" (Available at: https://tinyurl.com/ypxdx4nb). The stages of the cycle shown in the video were reinforced by the teacher's explanation, who alternated video segments with pauses to comment on each stage of the cycle.

Lesson 9: This lesson consisted of organizing and analyzing the data collected during the phenological observations. The teacher had previously structured a form in Google Forms, in which each group entered the results obtained regarding the predominant phenophases of the two trees in each observation they conducted. From this point, the groups examined the four factors listed in the form that could answer the scientific question: weather/climate, wind, animals, and human interference. For each observation, the groups had to indicate the condition of each of these factors and, finally, based on the data obtained, determine which one was most likely responsible for the observed changes. At the end of the lesson, the teacher generated graphs from the responses entered into the online form and analyzed them one by one with the students in order to identify the most likely factor.

Lesson 10: Each group received a poster board and a set of cards with images, terms, and connecting arrows (Available at: https://tinyurl.com/8hbj72ern). Based on what they learned in Lesson 8 and with the teacher's guidance, the groups were instructed to create a panel using the provided cards, representing the life cycle of the orchid tree, one of the observed species.

Lesson 11: The teacher revisited the problem-question and, based on the discussion of the factor identified in Lesson 9 (animals), the most likely answer was reached: pollination. Then, a brief explanation was given about what pollination is and how artificial lighting affects bats, identified as the pollinators of silk floss trees, based on a study cited in an online magazine article (Available at: https://tinyurl.com/2km49nm5). Finally, the groups answered, on a sheet of paper, whether their initial hypotheses were rejected or corroborated and why, which led to further discussion at the end.

Lesson 12: Each student wrote a short text that was required to include the following key terms: life cycle, phenophases, and pollination. At the end, the final questionnaire was administered individually, consisting of two open-ended and seven closed-ended questions (Available at: http://tinyurl.com/n5ed6yab), aimed at assessing the same learning outcomes addressed in the initial questionnaire.

2.4 Data analysis

Students' productions in each lesson and the teacher's field diary were used as instruments for data collection, which were analyzed using multiple methods in order to evaluate the sequence and propose modifications, thus validating it.

Content analysis was conducted on the hypotheses formulated by the students for the problem-question (Lesson 1) and on the individual texts produced (Lesson 12). This analysis aimed to assess the extent to which the hypotheses and texts adhered to what had been requested, which would indicate the need for adjustments to the problem-question and to the instructions of the task that required text production. The analysis was divided into three phases: pre-analysis; material exploration and treatment of results; inference and interpretation (Bardin, 2011). The productions were read (1st phase) and categorized based on context units (2nd phase), that is, the hypotheses according to whether or not they adhered to the problem-question (categories: adherent or non-adherent) and the texts according to whether or not they complied with the instructions (categories:

adequate or inadequate). The 3rd phase consisted of evaluating the frequency with which the categories appeared.

The initial and final questionnaires were analyzed according to the framework of Goode and Hatt (1972), who highlight certain indicators that suggest problems with the data collection instrument and that should be subject to revision by the researcher. To detect these indicators, both the wording of the questions and the students' responses were examined, since the adequacy of the responses to what was asked serves as an indicator of the quality of the questions. The aspects analyzed included: clarity and precision of the terms used, the format and order of the questions, and reflection on the value of each one, especially whether and how they were related to the learning objectives.

Data regarding phenophases were considered for analysis, since those related to weather conditions, wind, and presence of animals varied greatly within the same observation. This occurred because the class days differed among groups and due to rotation schedules implemented during the COVID-19 pandemic. Precision (the extent to which students' group data vary among themselves) and accuracy (the proximity or agreement of students' data with the standard defined by the teacher) were calculated (Lewandowski; Specht, 2015), providing evidence of the quality level of these data, which indicates whether changes are needed in the data collection form and in the citizen science protocol itself.

Regarding precision (P), each observation in each class was first evaluated using the formula: $P_t = (n / g) \times 100$, where t = class, n = number of groups in the class that recorded the same phenophase, and g = total number of groups in the class. Then, the mean of these P values for the same observation was calculated, resulting in the mean precision of each observation. Finally, the mean of the precision values across all observations generated the overall mean precision.

For the calculation of accuracy, each observation in each class was first evaluated using the formula: $A_t = (n / g) \times 100$, where t = class, n = number of groups that followed the teacher's classification (i.e., correctly identified the phenophase), and g = total number of groups in the class. Then, the mean of these A values for the same observation was calculated, resulting in the mean accuracy of each observation. Finally, the mean of the accuracy values across all observations generated the overall mean accuracy. For each mean value, the standard deviation was calculated.

The teacher's field diary was used to capture various situations or phenomena that cannot be obtained solely through questions, since the researcher experiences the daily life of the studied context (Minayo, 2007), an important aspect in action research processes (Francesconi; De Araújo, 2020). This diary contained students' spontaneous statements, their questions and suggestions regarding the lessons, as well as the teacher's perceptions, reflections, and impressions regarding his practices and lesson planning. Some excerpts from the field diary appear in full in the results and discussion section, with the description followed by the term "FD" in parentheses. For these data obtained from the field diary, a descriptive analysis was conducted, consisting of breaking down the data to identify patterns and regularities, and a theoretical analysis, which involves explaining these patterns and regularities, thus generating reflections on those data (Angrosino, 2007). These reflections led to proposed changes in the lessons of the sequence and in the citizen science protocol.

3 RESULTS AND DISCUSSION

In order to describe the adjustments and modifications proposed for the validation of the teaching-learning sequence, the results will be presented according to each lesson that composes it.

3.1 Lesson 1: Problem-question, hypothesis formulation, and initial questionnaire

Of the twelve hypotheses formulated by the student groups, six (50%) were considered relevant to the problem-question, as they included elements of the question that could be tested. As an example, a hypothesis from a group in the 3rd year A: "Given that LED lamps were installed on the court, it can be concluded that LED light interferes with fruit production."

The other six hypotheses (50%) were not considered relevant. Three of them mentioned the court renovation or the cemented soil as factors preventing fruit development, while the others attributed the difference to reduced sunlight exposure, differences in animals, and nutrient availability in the trees around the court compared to those in the square.

According to Barros (2008), a hypothesis should effectively clarify the problem under study; however, hypotheses are often not relevant, as observed in the six hypotheses that were not aligned with the problem-question. These issues may be caused by an inadequate formulation of the problem-question, since, as Carvalho (2018) states, a good problem should allow hypotheses to help determine its variables.

In light of this, we decided to reformulate the problem-question by adding more information to help students construct relevant hypotheses. The additional information included: 1) the presence of an open square around the court with silk floss trees; 2) that the trees were planted directly in the soil, without concrete around them; and 3) that all trees were regularly maintained by the city administration, including pruning, watering, and fertilization.

Thus, the reformulated problem-question was as follows: "On the street behind Joãozinho's house, there is a very open square with three beautiful silk floss trees (*Ceiba* sp.) that have both flowers and fruits. Three times a week, Joãozinho plays soccer at night on a court in his neighborhood. The court was renovated more than a year ago and received large LED floodlights to make it brighter. Right next to the court, there is another square with three more silk floss trees, but these do not have fruits, only flowers. Upon noticing this for the first time, Joãozinho became intrigued and began to wonder: What could explain this difference? Curious, he searched for some information and reached a few important conclusions about those trees: 1. They were of the same species; 2. They were planted at the same time; 3. They were planted directly in the soil, without concrete around them; and 4. They were regularly maintained by the city administration, including pruning, watering, and soil fertilization. Based on all this, it is now up to the group to propose a hypothesis to explain the difference between the trees in the two locations."

Based on the analysis of the initial questionnaire applied at the end of Lesson 1, some questions were added, while others were removed or reformulated.

Questions 1, 3, 4, 7, and 9 were removed. The decision to exclude Question 1 ("Describe what you see in the image below") and Question 3 ("Do you think the extinction of several plant species could affect your life? Justify your answer") was based on Goode and Hatt (1972), as they deviated from the main objectives, which focused on the life cycle of angiosperms. Questions 4 ("What do you think about studying plants?") and 7 ("Do you think that by studying plants it is possible to 'do science'?") were removed due to the high proportion of superficial responses ("it's cool" and "I don't know"), indicating inadequate formulation according to Goode and Hatt (1972) and Gil (1999), who suggest considering participants' prior knowledge. Question 9 ("In what way do you think it would be possible to collaborate with scientific research at school?") was also excluded, as the students' lack of prior experience with scientific research made it difficult to obtain relevant responses about collaboration in school-based scientific investigations.

Questions 5, 8, and 10 were reformulated. Question 5 ("What would you like to learn about plants?") was adjusted to request specific aspects of interest, making vague responses (e.g., "everything") more difficult and encouraging more detailed answers. Question 8 ("On a scale from 0 to 5, how much do you think it is possible to collaborate with scientific research at school?") was simplified to a choice between "yes," "no," or "I don't know," to facilitate the expression of students' perceptions regarding their ability to collaborate. On the other hand, Question 10 ("If you could collaborate with scientific research, would you be interested?") was adapted to use a 5-point Likert scale, allowing for a more precise assessment of students' interest in science.

Questions 2, 6, and 11 were kept unchanged, as they met the criteria proposed by Goode and Hatt (1972). With these modifications, a new initial questionnaire with seven questions was created (Available at: http://tinyurl.com/ynscp5fd). This questionnaire is more concise, reducing participant fatigue and the likelihood of superficial or unanswered responses, as pointed out by Melo and Bianchi (2015). Furthermore, its structure allows comparisons with the final questionnaire, facilitating the assessment of students' learning before and after participation (Bonney *et al.,* 2009).

3.2 Lesson 2: Explanation of phenophases

In his field diary, the teacher made the following observation: "I noticed that a closing activity was missing at the end of Lesson 2, for example, so that students could write what they understood from the concepts presented in the lesson" (FD). Observing the absence of an assessment element in the lesson and recognizing the importance of evaluation (Luckesi, 2011), it was proposed to include a simple exercise at the end of this lesson. Students should write the definition of phenophase and provide examples. Thompson *et al*. (2018) highlight the importance of students recognizing the phenological characteristics of plants when collecting data.

3.3 Lessons 3, 4, 5, and 6: Phenological observations

Regarding the data collection form, many observations about it were obtained from the field diary (FD), the main ones being:

- The teacher highlighted a question raised by a group member during discussions in Lesson 9: “But, teacher, is weather really a good factor to evaluate? Because we only observed the weather on each day, and there were only four observed days” (FD).

- In all observations, at least two groups from each class had significant difficulty identifying phenophases according to the categories in the form. Common doubts included: “What phenophase is this?” (FD); “Teacher, how do I know if the flower is open or not?” (FD); and even difficulty locating elements of the tree, such as: “Where are the fruits of the silk floss tree?” (FD). In this case, the teacher noted that he had not shown students what the fruits and flowers of the observed trees looked like, nor had he worked on the concepts involved in describing phenophases and transitions (open flowers, flower buds, and mature fruits). In addition, “students reported difficulty seeing the tree canopy, either due to height or excessive sunlight” (FD).

- After analyzing the completed forms, it was observed that all groups reported the presence of animals on the tree trunks, but hardly noticed floral visitors, which were not specified in the form. The teacher noticed that some students spent several minutes closely observing trunk details, which led to observations such as: “spider webs formed in the cracks of the tree bark” (FD).

- At the end of the observations, the teacher noted that the environments surrounding the trees had not changed and, due to their location away from heavy human traffic, changes were unlikely. Students also noticed this during the observations: “Teacher, nothing has changed since last time; everything around the tree is the same” (FD).

- The teacher observed that, in the form, the fields referring to observed animals, wind intensity, and surroundings were shared for both trees, which should not have occurred, as they were located in different environments: “Students had difficulty separating the information for the two trees in the form” (FD).

Considering the need to facilitate students’ observations and the completion of the form, the teacher reflected on possible improvements. Simplifying tasks can increase the engagement of citizen scientists (Balázs *et al.*, 2021) and prevent demotivation caused by confusing or demanding forms (Gommerman; Monroe, 2012). The proposed changes include:

- A new field to record weather conditions in the week prior to observation, allowing for a broader analysis of atmospheric conditions.

- Revision of phenophases: replacement of previous terms and creation of more precise categories for “transition between flowering and fruiting.”

- Reformulation of the “observed animals” field: changed to a direct question about the presence of animals on flowers, with response options and an additional field to name the animals.

- Removal of the “tree surroundings” field.

- Separation and detailing of fields for general information and observations of the two trees, with clear explanations of what should be recorded.

With all the changes mentioned above, a new data collection form was developed (Available at: https://tinyurl.com/zpbt23ax).

Regarding the data collected on phenophases, the mean accuracy (58% ± 25%) and mean precision (60% ± 23%) were low and showed high variability (Table 1), indicating that the groups seldom correctly identified phenophases (low accuracy) and also identified different phenophases among themselves in the same observation (low precision).

Table 1 – Mean values of accuracy and precision, and their respective standard deviations, of the phenophase identification data collected during the four observations.

	Accuracy	**Standard deviation**	**Precision**	**Standard-deviation**
Observation 1 (n = 12)	50%	25%	58%	14%
Observation 2 (n = 12)	42%	29%	42%	38%
Observation 3 (n = 12)	89%	20%	83%	24%
Observation 4 (n = 12)	50%	25%	58%	14%
Overall mean	58%	25%	60%	23%

Source: Authors (2024).

These data contrast with those from similar studies, such as that of Fuccillo *et al. (*2015), which reported an accuracy of 91.5% (standard deviation of 4.2%), a value considered high. The results obtained by these authors reinforce that volunteers who receive several hours of training provide reliable observations when following clear and standardized protocols, which did not occur in this sequence and may have led to the low accuracy and precision values obtained.

Reinforcing this idea, some of the teacher's observations recorded in the field diary highlight how the lack of such preparatory training generated problems in the execution of the observation and data collection stage:

- The teacher acknowledged that he did not provide specific guidance on what students should observe in the trees, which, combined with their inexperience, resulted in "many groups focusing their observations on non-relevant elements, such as the tree trunks or the soil around them" (FD).

- Students had their first contact with the form during Observation 1, "and the brief explanation given in Lesson 2 was not sufficient" (FD). Consequently, many doubts arose regarding how to carry out the instructions in the data collection form.

- More than half of the photographs obtained by the groups did not follow a standard in terms of positioning, framing, and lighting, since "no specific guidance was provided on how these photographs should be taken" (FD). This made comparisons and the analysis of phenophase changes more difficult.

To prevent problems in future applications of the sequence, a detailed guidance lesson was included, with the following elements:

- Form projection: The phenophase data collection form will be projected and explained in detail.

- Field simulation: The teacher will demonstrate how to perform the observations, focusing on three main aspects: (1) observing weather conditions in the sky; (2) analyzing the tree canopy to identify wind, leaves, flowers, and fruits; and (3) identifying floral visitors, using binoculars if necessary.

- Photo standardization: A consistent position, distance, and framing will be defined for photographing the trees, with one student from each group responsible for taking and sending the photos to the teacher to ensure standardization.

This guidance lesson aims to improve both the quality of the collected data and the participants' experience, based on studies showing that, with adequate training, participants can perform tasks with the same efficiency as professional scientists (Balázs *et al.,* 2021; Brown; Williams, 2019).

3.4 Lesson 7: Discussion on plant blindness and the importance of plants

Based on the teacher's own observation in the field diary that this lesson "was disconnected from the others" (FD) and was not aligned with the central objectives of the sequence, it was decided to exclude it. The teacher reassessed the total number of lessons to prevent the sequence from becoming excessively long. Interaction with plants during phenological observations, according to Ro (2019), may be more effective in overcoming plant blindness. Furthermore, the discussion on the plant life cycle and pollination, which remained in the sequence, may promote an implicit understanding of the importance of plants.

3.5 Lesson 8: Explanatory video on the life cycle of angiosperms

Many student reports indicated that, even after the video lesson, they still had difficulty understanding the life cycle, describing it as "difficult" (FD) and "having too many details" (FD). The teacher himself, reflecting on his practice, considered that there was "too much information presented in the video" (FD) and decided to simplify the plant life cycle shown in the video by omitting some stages and details to facilitate students' understanding. Presenting a detailed description of multiple stages of the cycle may increase difficulty and lead students to rely on memorization, which does not reflect true learning (Achterberg; Centa; Terrazan, 2021). This simplification process is known as didactic transposition, which, according to Chevallard (1991), involves transforming scientific knowledge into school knowledge. The teacher plays a crucial role in this process, facilitating the transposition of scientific knowledge into classroom teaching (Oliveira, 2014).

Still within the context of his reflections on this lesson, the teacher considered that additional resources were needed to maximize learning, as "the video alone was not sufficient" (FD). It is expected that teachers use multiple teaching strategies to enhance learning (Marcilio; Samia, 2006). Thus, in addition to the video, the lesson will include the use of the blackboard and slides to illustrate the stages of the angiosperm life cycle. This will allow students to record the life cycle in their notebooks and make connections between the video and the explanation provided.

3.6 Lesson 9: Organization and analysis of data

This lesson presented the greatest number of issues in the entire sequence, as identified by the teacher and reported in the field diary, namely:

- A single lesson proved insufficient for all the planned activities, which "were too many for the short class time" (FD). As a result, the activities had to be timed and quickly completed, which, in the teacher's view, "compromised the quality of execution" (FD).

- In addition to the limited time, the fact that students had not been previously introduced to the online form led to many doubts about how to submit the information, even with the teacher's brief initial explanation, "causing these steps to take longer than expected" (FD).

- The images of the tree selected by the teacher at four different moments and inserted into the online form "were not of good quality" (FD). Their purpose was for groups to identify the proportion of flowers and fruits in the orchid tree, which showed phenophase changes over three months, transitioning from flowering to fruiting. Although the photos were accurate in capturing important phenological events (Crimmins; Crimmins, 2008), visualization was compromised due to distance and excessive brightness, giving the false impression that the tree remained unchanged.

- Discussions about which factor could be responsible for the changes in the proportions of flowers and fruits in the orchid tree were hindered because "the graphs generated from the responses in the online form were highly variable and inconsistent" (FD), since observations within the same class were conducted on different days (due to student rotation), which alters factors such as weather conditions and wind intensity. This made it impossible to identify a main factor responsible for fruiting. Thus, without a clear answer emerging from the students, the teacher "had to guide them to conclude that animals were the factor responsible for fruiting, due to pollination" (FD).

In this context, the following changes were proposed:

- Structuring the protocol on the Anecdata platform (Available at: https://www.anecdata.org/projects/view/1061): Students will submit their collected data on the *Anecdata* platform, which will be explained and simulated by the teacher during the lesson. The platform facilitates students' work by providing fields identical to those in the data collection form and promotes open data sharing, aligned with citizen science principles (Robinson *et al.,* 2018).

- Division and extension of time: The lesson will be divided into two sessions to provide more time for the execution of the proposed activities.

- Graph analysis: In the following lesson, the teacher will present graphs generated in *Anecdata* regarding weather conditions, wind intensity, and floral visitors. Students, with teacher mediation, will interpret the graphs and discuss which factor influenced fruiting, with the conclusion reserved for a later moment.

- Schedule adjustment: The lessons will be reordered to take place after the lesson on assembling the angiosperm life cycle, improving the logical sequence of activities.

3.7 Lesson 10: Construction of the panel representing the life cycle of angiosperms

The main issue in this lesson was time, as most groups had considerable difficulty completing the activity within a single class period, given the large number of cards required for constructing the panel. Since the video lesson had taken place the previous week, “many had forgotten the stages of the cycle” (FD) and were not allowed to consult any materials. Throughout the lesson, it was common to hear questions such as: “There’s too much to include, teacher” (FD), “Teacher, is this placed correctly?” (FD), and “Where do I put this?” (FD). As a result, the teacher had to constantly assist the groups to ensure that all panels were completed on time, acknowledging the importance of time in educational activities, as highlighted by Guimarães and Giordan (2011). Although this assistance ensured that the panels were correctly assembled, it also raised doubts about the students’ actual understanding of the life cycle.

In light of this, the teacher reflected on implementing some changes in this lesson to optimize time and make the activity more feasible:

- Reduction and modification of the cards used to construct the life cycle panel (Available at: https://tinyurl.com/33vrchr6), simplifying the activity in accordance with the proposal of Lesson 8. The main changes include: (1) the elimination of the detailed representation of the embryo sac due to its complexity, maintaining only the representation of the mature sac and the spores generated by meiosis; and (2) the inclusion of an image of the pollen grain forming the pollen tube, which was present in the video but “had not been considered in the preparation of the cards” (FD).

- Execution of the activity without teacher assistance: This aims to ensure greater student autonomy and strengthen active learning with an investigative character. Autonomy, linked to the freedom to construct and reconstruct knowledge (Freire, 1996), will allow the panels to reflect the students’ actual learning. In addition, students will be allowed to consult their notebooks to associate information with the cards, thus reducing doubts.

3.8 Lesson 11: Revisiting the problem-question and hypotheses

- Although no problems were identified in this lesson and no mentions were recorded in the field diary, the teacher decided to adjust it to align with the changes made in previous lessons, ensuring logical organization and sequencing of activities (Guimarães; Giordan, 2011). Initially, students arrived at the answer to the scientific question during the data organization and analysis lesson; however, with the changes, the answer will now be reached in this lesson. The teacher will begin by revisiting the scientific question, presenting the “answer key” for the angiosperm life cycle panel, and guiding students to identify pollination as the factor responsible for fruiting based on the graphs and the theoretical knowledge learned. The explanation of pollination and the analysis of data will enable students to reassess the silk floss tree problem-question in light of new knowledge. In this regard, Bellucco and Carvalho (2014) emphasize that students must have a solid theoretical foundation to interpret phenomena, rather than relying solely on neutral observations. At the end of the lesson, each group should indicate whether their hypotheses were confirmed or rejected, providing justification for their conclusions.

3.9 Lesson 12: Keyword-based text and final questionnaire

In the analysis of the texts produced by students, it was found that 60% were inadequate, with 70% of these texts not mentioning the keyword “phenophase.” This suggests that students did not master the term, possibly due to limited exposure to it. To improve understanding, the teacher decided to replace “phenophase” with “fruiting,” which had been extensively addressed in the sequence, facilitating its articulation with the terms “life cycle” and “pollination.”

Based on the analysis of the final questionnaire applied at the end of Lesson 12, some questions were excluded and most of them were reformulated:

- Questions 3 (“I am able to observe plants in greater detail and identify their stages”) and 4 (“I was able to learn about the life cycle of terrestrial plants and their respective stages”) were excluded because, based on the evaluation of their relevance (Goode; Hatt, 1972), it was deemed unnecessary for students to assess their own learning, as other instruments in the sequence already measure these aspects.

- Question 1 (“Express in three sentences what most positively and negatively caught your attention in the project. Give suggestions for improvement”) was divided into two, as recommended for cases in which a single question encompasses multiple objectives (Goode; Hatt, 1972). Responses revealed that most students did not follow the original instructions, which required positive aspects, negative aspects, and suggestions. Therefore, two separate questions were created: one for positive aspects and another for negative aspects and suggestions, aiming to obtain more specific and detailed responses.

- Question 2 (“For each lesson or stage of the project, assign a number from 1 to 5 corresponding to how much you liked or were interested in it”) was modified. Students were asked to evaluate the difficulty of each stage of the sequence, rather than simply expressing interest and satisfaction, thus improving the objectivity of the question (Goode; Hatt, 1972). This change also helps identify which stages may require adjustments. In addition, a more detailed description of the stages was included to help students better recall each one, as some reported difficulty remembering them.

- In Question 6 (“Now that you have participated in the stages of the scientific process in this project, how capable do you feel (from 1 to 10) of contributing to each of them if you were to participate in other projects?”), a reorganization of the description of the scientific stages was proposed, separating tree observation from data submission and removing the conclusion stage. This change aims to provide greater clarity (Goode; Hatt, 1972) and facilitate the association of descriptors with the activities carried out by students at each stage.

- Question 9 (“Have you started to notice/observe plants more?”) was modified to be identical and comparable to Question 1 of the new initial questionnaire, since the previous version induced positive responses (Melo; Bianchi, 2015) and did not allow measurement of behavioral frequency, which is crucial for assessing possible changes resulting from participation in the sequence.

- Question 10 (“How can plant extinction affect your life?”) had its focus changed from “plant extinction” to “pollinator extinction,” aligning it with the sequence’s content on pollination and its impact, helping students understand the consequences of such extinction.

- Questions 5 (“Are you interested in studying any additional topics about plants after this project?”), 7 (“Do you see yourself pursuing a scientific career?”), and 8 (“If you could collaborate with other scientific research projects like this one, would you be interested?”) remained unchanged, as no issues were identified (Goode; Hatt, 1972).

All questions were numbered and organized in a way compatible with the order of questions in the initial questionnaire, forming the new final questionnaire (Available at: https://tinyurl.com/5d4yh2hh).

4 CONCLUSION

Based on the evaluation of the pilot test application of the teaching-learning sequence, several aspects were identified for improvement, which served as a reference for proposing changes to the lessons and instruments of the sequence, as well as to the citizen science protocol.

Among the main changes, the following stand out: 1. Reduction in the number of questions in the initial and final questionnaires, making them more direct and allowing for a clearer assessment of the proposed learning objectives, as well as including questions that enable comparisons before and after participation; 2. Reformulation of the problem-question, providing more information to students in order to avoid the formulation of many non-relevant or non-aligned hypotheses; 3. Inclusion of a guidance lesson for phenological observations, aiming to improve students’ observation and data collection skills, and potentially generating higher-quality data; 4. Modification of the data collection form, including: a. Addition of a question about weather conditions in the week prior to observation, to broaden participants’ understanding of the dynamics of this factor; b. Inclusion of a field to record the quantities and proportions of leaves, flowers, and fruits, facilitating subsequent data analysis; c. Inclusion of a separate field for the “wind intensity” factor for each tree; and d. Specification that only floral visitors should be observed, requiring the recording of their presence or absence and, when possible, their identification; and 5. Inclusion of the protocol on the Anecdata platform, following the principle that data from citizen science projects should be openly accessible.

The validation of the sequence made it more aligned with the assumptions and principles of citizen science, as it now includes a clear and executable protocol for the target audience that enables the collection of genuine scientific data. These data can be evaluated in terms of quality and integrated into a citizen science platform where they are openly available, with the potential to be accessed by scientists and to contribute to various research efforts. Furthermore, the validated sequence and protocol can be applied and adapted to other contexts according to educational objectives. The modified version of the teaching-learning sequence with citizen science is available for download, free of charge and openly accessible (in accordance with citizen science principles), allowing interested users to apply and adapt it to their needs and contexts, under a perspective of continuous improvement (Monteiro; Ghilardi-Lopes, 2024).

TESTE-PILOTO E VALIDAÇÃO DE UMA SEQUÊNCIA DE ENSINO-APRENDIZAGEM CONTENDO PROTOCOLO DE CIÊNCIA CIDADÃ DE OBSERVAÇÃO FENOLÓGICA DE ÁRVORES

RESUMO

A ciência cidadã envolve a participação do público na ciência, em projetos contendo protocolos com uma pergunta científica e que envolvem, na maioria dos casos, a coleta de dados. Esses protocolos precisam ser testados e aperfeiçoados por meio de testes-piloto. O presente trabalho tem como objetivo validar uma sequência de ensino-aprendizagem de caráter investigativo, que abrange um protocolo de ciência cidadã escolar inédito, de observação fenológica de árvores, adequado a estudantes do ensino médio. Para isso, foi realizado um teste-piloto da sequência. Os resultados obtidos evidenciaram a necessidade de mudanças no protocolo de ciência cidadã e em algumas aulas da sequência. Dentre as alterações, destacam-se: 1. Inclusão de uma etapa de orientação mais detalhada para a coleta de dados pelos estudantes; 2. Reestruturação do formulário de coleta de dados para torná-lo mais claro e objetivo e 3. Inclusão do projeto numa plataforma on-line de ciência cidadã.

PALAVRAS-CHAVE: Ciclo de vida das angiospermas. Formulário de coleta de dados. Formação dos cientistas cidadãos.

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