

Article

Is It Possible to Apply Inquiry in the First Level of Primary School without Hindering the Acquisition of Scientific Competencies? Perspectives of Pupils and Their Pre-Service Teacher

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Abstract: The aim of this study is to assess the application of inquiry as a teaching strategy during the practicum of a pre-service teacher and to verify the acquisition of scientific skills by her students. The importance of this study is the application of inquiry as a teaching strategy at lower levels of basic education to contribute to scientific skills and scientific literacy. The sample consisted of 27 pupils in the first level of primary education and one pre-service teacher in a Spanish school. The methodology used was a case study with a participatory experimental design, incorporating guided discovery and teacher questioning focused on plant growth. The results indicate that the pupils improved their understanding and assimilation of content related to plant functions, scientific procedures, and critical thinking. The pre-service teacher demonstrated mastery of the inquiry-based methodology, confirming an adequate level of both pedagogical and scientific competence. Some suggestions are provided to enhance her training. The study concludes by demonstrating that it is possible to implement inquiry at any educational level, despite the potential limitations of the students. It is recommended that pre-service teachers receive comprehensive training to enable them to facilitate the acquisition of scientific competence among their students.

Keywords: inquiry; case study; preservice teacher; practicum; first level; primary education; discovery; learning; scientific skills



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1. Introduction

Among the various facets of knowledge, the teaching of experimental sciences constitutes a central axis around which several elements revolve, including learning and teaching difficulties, student performance, the curriculum, and the programs of scientific subjects. The issues stemming from each scientific discipline have always been a focal point of attention, but the new challenges of society due to technological advances (new products, greater availability of information, inventions that modify lifestyles, etc.) and the fact that people need to support themselves in key competencies that allow them to adapt to a world characterized by change, complexity, and interdependence [1] demand an update of work methodology in the classroom [2] and innovative proposals for teacher training [3], thereby increasing interest in understanding how teaching and learning occur by professionals of the didactics.

The recommendations of the National Research Council [4] and the Rocard report [5] to improve scientific competence (understanding this as the ability to interact with issues related to science and with the ideas of science as a reflective citizen, according to the

OECD [6] of the students) pointed to inquiry (in a broad sense) as an appropriate procedure or procedures for teaching and learning scientific knowledge. The countries took the recommendations into account, extending them to basic educational stages. In the case of Spain, the report ENCIENDE [7] was published, in which the analysis and proposals for bringing science closer to the school world are presented. In this report, Jiménez, Sanmartí, and Couto [7] reflected on the need for adequate science teaching through methodological changes, effective evaluation, the design of innovative teaching materials, and effective initial and continuous training of teachers. In the same report, Rodríguez and López-Ruiz [7] justify the approach of scientists to school classrooms and propose reorienting some of the traditional activities to investigative activities. The report summarizes the need to renew science teaching towards inquiry-based teaching strategies as a tool for both scientific literacy (understanding this as the knowledge and understanding of scientific concepts and processes necessary for making personal decisions, participating in civic and cultural affairs, and economic productivity, according to the National Research Council [4]) and the correct development of scientific competence.

In this way, one of the aspects explored by the Didactics of Experimental Sciences is the methodology used in teaching scientific content. Without underestimating the importance of other variables involved in the educational process, methodology plays a crucial role in the transmission of knowledge. The success of teaching depends on how and when it is applied.

Among the numerous techniques and strategies encompassed by teaching methodology, it is worth emphasizing inquiry (in its broad sense, IBSE, or inquiry-based science education) as a potential method for teaching and learning scientific content. Garritz [8] pointed out that defining the concept of inquiry can be complex since it depends on the context and the teacher's interpretation of the term, as well as the objectives set and the teacher's role [9]. Often, teachers employ practical actions with scientific procedures but fail to promote critical thinking. To avoid this situation, it is essential to encourage the construction of models and theories based on evidence, with student reflection and reasoning [10], sequential procedures [11], or what Romero-Ariza [12] calls quality inquiry. Numerous studies have examined inquiry from various angles and educational levels, with most of them focusing on university or secondary education levels. There is limited evidence in the literature to suggest that this methodology was widely applied in earlier stages, with a relatively small number of teachers implementing it. Within basic or primary education, especially at lower levels, there is a scarcity of literature on this topic in major databases like WOS and SCOPUS. However, in early childhood education, there are several articles addressing inquiry in the classroom [13–17].

Resistance to implementing inquiry in the classroom can be attributed to various factors. Romero-Ariza et al. [18] and Fang [19] highlight aspects related to official curriculum design, resource availability, and classroom dynamics. In the context of the first year of basic or primary education (6 years old), these challenges can be exacerbated due to the psychomotor and cognitive characteristics of the students. An example would be persistent preconceptions stemming from early childhood, such as not considering plants as living beings [20].

It is important to note that students at the first level of primary education are in an intellectual transition phase, evolving from intuitive thinking associated with perceptual data typical of early childhood toward operational thinking that includes the ability to formulate hypotheses, engage in reflection, and employ metacognition [21]. In the early years of primary education, children also learn cognitive processes such as mental imagery (constructing mental images independently) and retrieval (searching their memory for corresponding letters when spelling a word) [22]. According to Ballesteros and García [23], children in the early levels of primary education often struggle with logical reasoning when faced with abstract concepts (intuitive and concrete thinking) and encounter difficulties in analysis and synthesis. Teachers' communication skills also have an impact on science teaching methodology. In a study of lower primary school teachers, Solé-Llussà et al. [17]

and Lofgren et al. [24] observed that these teachers tended to rely heavily on scientific descriptions in their explanations, indicating a need for more exploratory discussions.

As a result, the implementation of inquiry necessitates the utilization of exploratory scientific procedures and a methodology closely aligned with the ways in which scientists investigate the environment and generate scientific knowledge [25–27]. Guided inquiry in the classroom has the potential to enhance students' acquisition of scientific knowledge [28], promote argumentative capacity based on scientific procedures such as observation, discovery, comparison, explanation, discussion, and questioning [29,30], and can be further enriched when combined with other strategies, such as collaborative learning [31,32].

Given these considerations, this paper contends that, regardless of the limitations that may be present among students at the early stages of primary education concerning certain procedures and notwithstanding any challenges perceived by teachers, the adoption of inquiry should not be dismissed. We do not mean that inquiry cannot be applied, but that teachers do not do it regularly, perhaps due to discretion, prudence, or a lack of self-confidence. From the authors' experience with students in training and conversations with teachers, it has been seen that it is not common in the first and second years of primary education.

This paper will investigate this matter through an analysis of how a pre-service teacher manages the implementation of inquiry in a first-year primary school classroom and how students at a specific school respond to inquiry-based activities. The study does not intend to generalize the results to all students at this level and stage of the school world, but we want to generalize the recommendation for undecided teachers.

For this reason, the following objectives are addressed:

- Know the competence of a pre-service teacher in applying inquiry with pupils in the first year of primary education.
- Know the ability of first-grade primary education pupils to acquire scientific competence and learn about natural science topics through the use of inquiry.
- Stimulate and encourage the teachers to use inquiry as an active and participatory methodology for teaching natural science topics to 6-year-old students.

Based on the established objectives, the hypothesis presented in this work is that it is feasible to implement inquiry-based teaching in the early stages of primary education, specifically in the first year, without impeding the acquisition of competences and knowledge.

2. Materials and Methods

2.1. Methodology

This work constitutes an exploratory case study, employing assembly techniques and individual structured interviews during the practicum period of a pre-service teacher in the first level of primary education at a school in Valladolid, Spain. In the classroom intervention, we applied structured inquiry methodology, as defined by Banchi and Bell [33], in which the teacher guides the development of activities, asks questions, and provides guidance so that students achieve the established goals. This approach involved a combination of demonstrative sessions, which included instructional processes led by the teacher, participatory operational sessions, where students engaged in procedures and expressed themselves orally in response to the teacher's questions, and sessions aligned with the five phases proposed for inquiry-based learning and teaching [34,35]: motivate, explore, explain, investigate, and evaluate. The classroom intervention was organized in five stages in which the teacher collected data: the contextualization stage (assembly and group question), the exploratory stage (individual interview), the investigative stage (group activation question, student files, group question about meteorology), and the evaluation stage (individual interview and group reflection question).

Respecting the experimental procedures, in which the students sowed bean and lentil seeds, the pre-service teacher organized the class into working groups of 5–6 students, randomly selected. Individual interviews were conducted at two points in the study: before (Pre) in the exploratory stage and after (Post) in the evaluation stage. These interviews

consisted of a series of linked questions, including cognitively demanding ones [36,37]. They primarily served to obtain hypotheses from students, who, at the age of 6, still possess limited skills for independent articulation. Additionally, these interviews aimed to assess argumentative capacity. Group activation questions were posed prior to the beginning of the intervention, and synthesis and learning verification questions were asked at the end of the intervention. In addition to the data obtained, we conducted a qualitative analysis of the materials (worksheets) produced by the working groups, as well as the students' responses, employing content analysis techniques [38]. For this purpose, a categorical sum was initially carried out, establishing categories (in parallel to a direct prior interpretation of the meaning) whose taxonomy was based on responses in the same sense (positive, negative, or similar meaning), responses with semantic similarity, responses with the same variables involved, and responses (on the worksheets) with a degree of closeness to the required result. Subsequently, the content analysis of the categories was carried out based on the criteria of correlation of the categories with previous persistent ideas, ideas modified after intervention, correct result from a scientific point of view, volume of contents involved, implication of the answers, quality of argument, and, in all cases, comparing with other cases and existing information in the literature.

The research problem was implicitly addressed through targeted questions. The hypothesis put forward in the study is descriptive, following Hernández, Fernández, and Baptista's [39] framework, similar to the hypotheses derived from the students' responses.

2.2. Sample

The sample consisted of 27 pupils that were 6 years old, comprising 12 boys and 15 girls, all in the first year of primary education, along with one preservice teacher. The intervention spanned 8 weeks and covered inclusive content related to plants (functions, parts, processes, and factors). This content aligned with the official primary education curriculum in force at the time of the intervention. Specifically, it encompassed "Initiation to scientific activity", "Basic and complex scientific procedures" (Block I), "Living beings", and "Plants: morphology, functions, and seeds" from Block II of the Natural Sciences knowledge area in the official primary education curriculum of Castile and León [40].

The level of competence in the scientific field of the students under study has been considered to be what they should have at the end of the childhood education stage, which constitutes the basis at the beginning of the primary education stage.

On the other hand, the competence of the pre-service teacher was considered at the beginning of the study, like the one that a student of the degree must have in the fourth year of the degree with approved scientific subjects and who, by default, does not know in-depth strategies based on inquiry. During the study, competence was determined continuously through the periodic reports that she had to make and give, during the practicum period, to the academic tutor, who is the first author of this work. Their competence was also evaluated regularly in the periodic meetings with the academic tutor established by the internship regulations, where the preservice teacher expressed reflections on activity at school, difficulties, solutions, etc. In addition, she was evaluated through the final practice report (unpublished) and with the grade suggested by the school's tutor teacher.

3. Development

3.1. Contextualisation Stage

To set the context for the activity and introduce the topic, the pupils were led to the school playground to observe the vegetation within and around the school, which included various trees, shrubs, and herbaceous plants. As a group, they were asked the following questions: "Can you distinguish between objects created by humans and natural elements?"; "Among the natural elements, do you notice the presence of vegetation?"; "Have you observed whether the plants and trees are consistently the same size?"; and "Do they share the same height, possess similar amounts of leaves, and have identical colors?"

The purpose of this question is to draw attention to plants and investigate the concept of plant blindness [41].

To familiarize the students with the problem and achieve the objective of focusing on the subject of plants, they were posed additional questions as a group to gather their initial thoughts about plants and to understand the criteria they use to classify them as living entities. The questions included: “Are plants considered living organisms?”; “What leads you to believe that plants are living entities?”; “Are seeds living organisms?”; and “How do plants come into existence?”

3.2. Exploratory Stage

Through individual interviews, the teacher posed a series of guided questions about germination and plant growth. These questions were interconnected and intended to prompt students to contemplate a scenario that impacts plants, necessitating the application of diverse knowledge and fostering implicit argumentative discourse. The objective was to stimulate cognitive engagement with the students’ pre-existing ideas, promote reflection, and foster critical thinking through logical reasoning, all tailored to the context of first-grade primary education. The questions presented were as follows:

- (a) Where does a plant come from?
- (b) What will happen in a few days if we plant a seed (beans and lentils) without watering and light?
- (c) What if we do not water it?
- (d) What will happen if we water it every day?
- (e) What will happen if we put one in the window with light when it has germinated?
- (f) What if it is dark inside a cupboard?
- (g) What would happen if I did not change the container to a larger one when the plant had grown?

Some of these questions serve as confirmatory inquiries for earlier questions. For instance, questions “c” and “f” are designed to validate the responses to question “b”.

The analysis of the responses is detailed in the chapter titled “Results and Interpretation”.

3.3. Investigative Stage

For the planning of the experiment, activation questions were asked as a group, the answers to which are analyzed in the following chapter. The first question was: “Do you think that if we plant the lentils and beans, a plant will grow?” The answer was not unanimous, with some students saying “yes” and others saying “no”. The teacher told them that they would carry out an experiment to find out the solution.

A second question was asked for variables: “What do plants need to live and grow?”, the answers to which are shown in Figure 1.

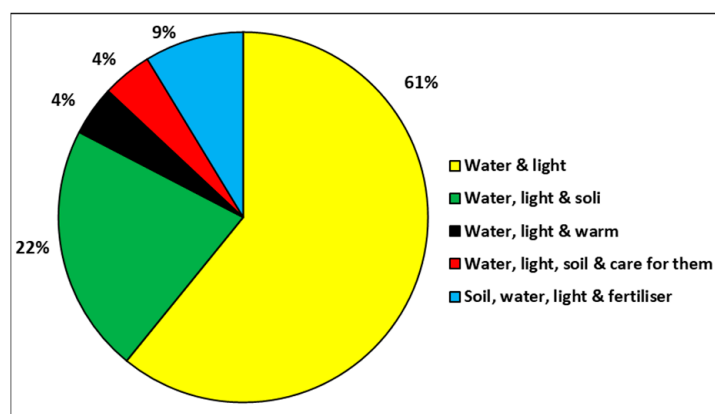


Figure 1. Responses to the question “What do plants need to live and grow?”.

The teacher goes on to ask more questions: “How would we know if the seed grows?” The pupils answer, “By planting it!”. Again, the teacher asks, “How do we do that?”. A whirlwind of generic answers ensues, reminiscent of the answers to the initial question: “with water and soil, in a pot. . .”.

The teacher explains that they will use beans and lentils, yogurt pots, and wet cotton wool, asking them at the same time, “What do you think cotton wool is for?” They answer that it is to give warmth to the plant, to give humidity, to keep it in the dark, etc.

At this point, the identification of variables has been checked, and an instructional stage begins. The teacher gives them indications to begin germination, given that psychological and cognitive development could limit the explanatory, procedural, and argumentative possibilities for the experimental design (although many pupils already knew about it because they had done something similar in early childhood education). The experiment is organized in two phases.

First phase: The teacher gave instructions to place two beans and two lentils between cotton wool for each beaker, with the suggestion of watering every 2 or 3 days, although the decision had to be taken by the participants depending on the degree of humidity of the cotton wool (not wet). Half of each set of cups per group was placed in an unlit place (inside a cupboard). The aim of this phase is to show them that water is relevant for the growing root but that it is not dependent on light. The pupils, in heterogeneous collaborative groups, place the cotton wool and various seeds in the yogurt pots with the addition of water. During the first 2 weeks, they monitored the growth of the seeds in the cotton by observing the seedling (root and stem) and expressing orally and as a group what they appreciated, without making a written record.

Second phase: When the seeds germinated (two weeks later from the start of the experiment), they were transplanted into another yogurt pot with soil (called a “pot”), and each group chose which seedling was watered, how often it was watered, and which remained in the dark. Systematic observation was carried out from then on, including daily recording of the weather conditions: sunny, cloudy, rainy, etc.:

- First week in pot: leaf traits (stretched, size, shade, etc.)
- Second week in pot: traits of leaves (stretched, size, shade, etc.). The teacher asks about the differences between light and no light, watering and non-watering, without a written record.
- Third week in pot: collection of observations on a systematic information sheet:
 - Type of plant seed;
 - Sowing date;
 - Irrigation (period);
 - Date of germination;
 - Measurements in the first week after germination and in the fifth week;
 - Features;
 - Drawing.

The teacher collects answers orally to the question, “How can temperature affect plants?” At the end of the month, they were asked to reflect on the weather and the possible deviation from what was expected for the time of the year.

Throughout the development of the intervention, the pupils analyzed the data, either collected or with the answers to the questions, by comparing different plants in different contexts. They deduced what could happen in those contexts, predicted the outcome, planned actions, and made decisions such as which plants they would water and how they would do it, which ones would have light, etc.

3.4. Evaluative Stage

At the end of the activity and as a reinforcement and evaluation of learning, the initial survey was carried out again using the individual interview (post). With group reflection, they argued the interpretation of the results and the answers expressed and, above all,

whether these results coincided with what they had predicted would happen (hypothesis verification). With all the information, conclusions were drawn.

4. Results and Interpretation

4.1. In the Contextualization Stage

On the school playground, when asked “Have you ever noticed if plants and trees are always the same size?”, the unanimous answer was “no”. They either “grow” or some “dry up and come out again”. It seems clear to the students that plants have some function in common with living things (“they grow”, “they dry up and come out again”), although the subsequent question, “Are plants living things?” The responses, collected informally, were:

1. Yes, because it is like a person, but without the features.
2. Yes, because they grow.
3. Yes, because they drink, they eat, and they grow.
4. Yes, because they give us oxygen and they grow.
5. Yes, because they are alive and in nature.
6. Yes, because they can die, they can live, and they can grow.
7. Yes, because they eat, breathe, and grow.
8. Yes, because they grow, eat, and need water.
9. Yes, because they breathe like animals.
10. Seeds are living things, like when mothers are pregnant.

They are asked, “How do plants appear?” There are a majority of answers that point out that it comes from a seed.

The research problem deduced from the answers to the group questions was: On which factors does the growth of a plant depend?

4.2. In the Exploratory Stage

Subsequently, the students are presented with individual questions. The primary objectives of these questions are to pinpoint their preexisting ideas with greater precision, extract hypotheses, and identify variables. Concerning these individual interviews, the responses to the question “Where does a plant come from?” (Figure 2) reveals that the students had no trouble connecting the plant with the seed. However, they encountered difficulties in linking the plant to the root, as if one were not considered a component of the other.

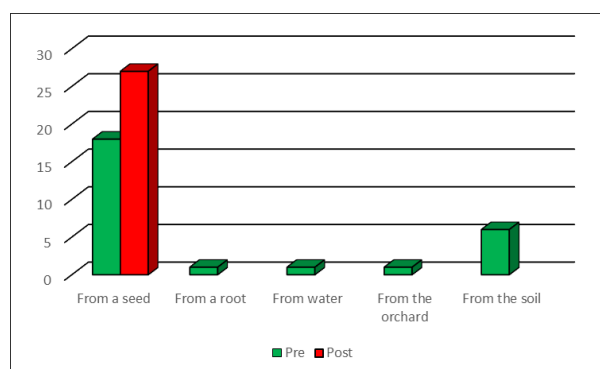


Figure 2. Responses to the question “Where does a plant come from?” before the intervention (Pre) and after the intervention (Post).

The remaining answers are likely to be associated with ideas that have been significantly influenced by the way plants are treated, possibly stemming from the cultural and perceptual origins of their preexisting ideas.

Regarding the question “What will happen in a few days if we plant a seed (beans and lentils) without watering and light?”, most students (Figure 3) offer intuitive responses, suggesting that a plant will develop (“grow”) from the seed. However, they typically do

not specify the processes involved, but there is an implicit understanding of biological processes. One response correctly acknowledges the root as part of the plant and the evolution of the seed. Nonetheless, none of these responses take into consideration the absence of moisture or water, implying that it is unnecessary to water a seed for the plant to grow. In this context, there is one response that does consider irrigation, suggesting that the plant's development depends on the presence of moisture. Conversely, none of the students mention the absence of light.

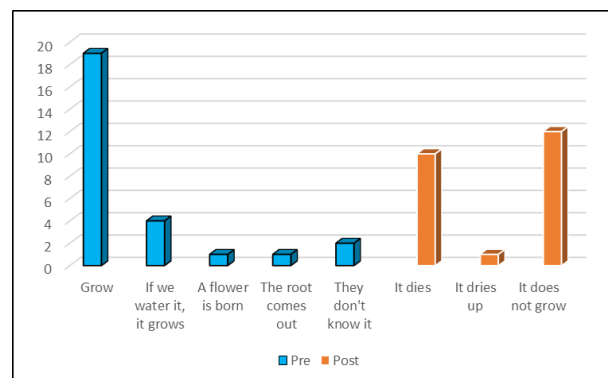


Figure 3. Responses to the question “What will happen in a few days if we plant a seed (beans and lentils) without watering and light?” before the intervention (Pre) and after the intervention (Post).

The question “What will happen if we water it?” elicits responses (Figure 4) that generally align with varying degrees of scientific precision. Among all the responses, 23 reflect the pupils’ understanding that the provision of water is beneficial for the plant’s development. They infer that a plant forms or grows, but without specifying that it is the plant that grows from the root rather than the seed (“it will grow” and “a plant comes out”). Furthermore, there is limited reference to the germination processes. They do not mention the morphology of the plant (the root) as part of the plant’s growth, and it remains unclear whether they understand that it is a component of the germination process since they describe a plant as “coming out”, as though it were something magical. One response demonstrates a strong anthropocentric influence, stating, “a flower comes out”, with imprecision regarding plant processes.

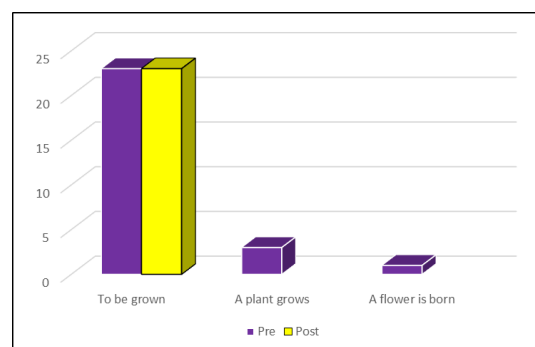


Figure 4. Responses to the question “What will happen if we water it?” before the intervention (Pre) and after the intervention (Post).

In response to the question “What if we do not water it?” there are common answers indicating that the plant does not develop, expressed in various ways (Figure 5). Two of these responses are closely aligned with scientific expressions (“it dries up” and “it dies”), which may suggest that the pupils comprehend the necessity of water for sustaining life. The answer “it rots” appears to be a colloquial term of perceptual origin, where the pupil erroneously associates the deteriorated appearance of the plant with a physico-

chemical process, such as putrefaction. The expression “does not form” is very generic and unscientific. Apart from stating the necessity of water, it does not connect to development, processes, or functions. Lastly, the term “does not grow” is the most commonly used by the pupils, suggesting an association of water as a liquid element with the function of nutrition and related processes. However, it is important to note that this answer implies that the plant has already germinated, which is not necessarily the case.

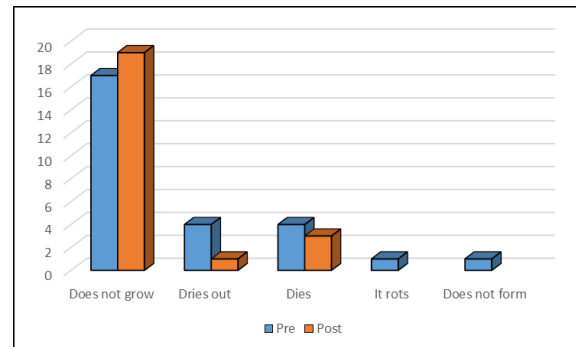


Figure 5. Responses to the question “What if we do not water it?” before the intervention (Pre) and after the intervention (Post).

It is worth noting that when comparing the responses to this question with the answers to the question “What will happen in a few days if we plant a seed (beans and lentils) without watering it and without light?” the context of the answers differs, despite both addressing the issue of not watering the plant. In the latter question, despite acknowledging the absence of watering and light, the absence of watering does not seem to be taken into account. However, in the specific question “What if we do not water it?” the pupils firmly recognize the plant’s need for water for its development.

Regarding the question “What will happen if we water it every day?” the majority of the responses (Figure 6) indicate that excessive watering is detrimental to the plant. Out of these answers, 6 participants demonstrate anthropocentrism (“it drowns”), while another 19 participants state that “it does not grow”, suggesting that excessive water hampers the plant’s growth but not necessarily its survival. It is worth noting that one pupil believes that excess water is beneficial for the plant, drawing an almost arithmetic relationship between the quantity of water and growth.

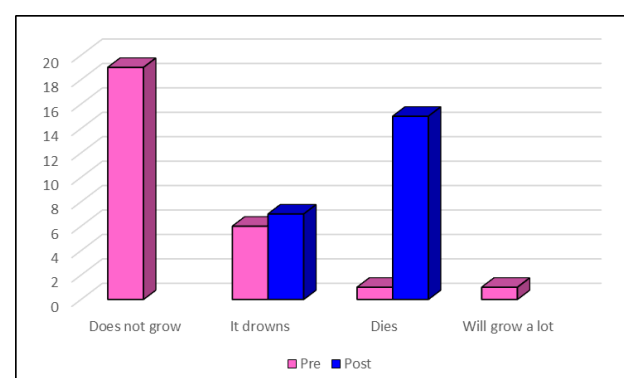


Figure 6. Responses to the question “What will happen if we water it every day?” before the intervention (Pre) and after the intervention (Post).

Regarding the question “What will happen if we place one by the window with light after it has germinated?” the majority of the responses (Figure 7) suggest that the pupils believe exposure to light is beneficial for the plant. There is a relative minority (four

responses) who consider exposure to light as detrimental, with responses such as “it dries out”, “it rots”, and “it does not grow”.

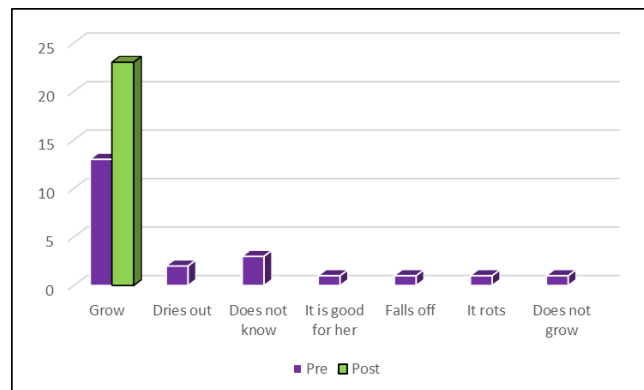


Figure 7. Responses to the question “What will happen if we put one in the window with light when it has germinated?” before the intervention (Pre) and after the intervention (Post).

In response to the question “What if it is placed in the dark inside a cupboard?” (Figure 8), it is evident that the pupils believe that in such a situation, the plant will encounter difficulties in surviving (“it dies”) or, at the very least, in growing (“it does not grow” and “it remains small”). Their expressions are imprecise but consistently negative for the plant (“it rots” and “it dries up”), with the exception of a few who think “it will grow”. There’s another response, “it does not breathe”, which is not scientifically accurate. In this case, the student appears to relate the question to the enclosed space rather than the absence of light and may be influenced by anthropocentrism. Given the students’ educational level, it can be assumed that when they mention “breathing”, they are referring to general human processes (pulmonary respiration). Strictly speaking, plants do undergo a form of respiration even in the cabinet. Notably, there’s no mention of light as a crucial factor in plant development.

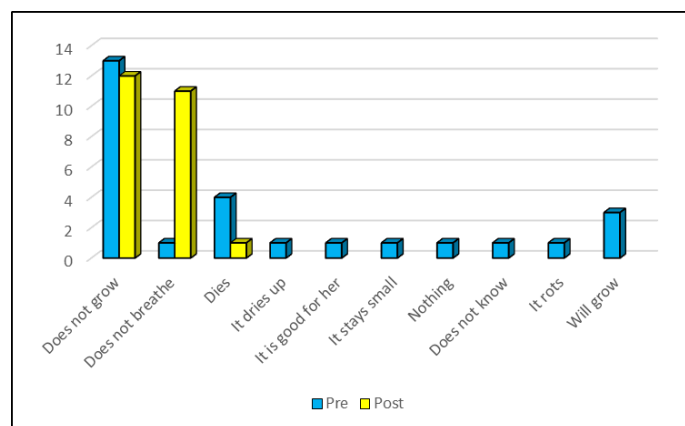


Figure 8. Responses to the question “What if it is dark inside a cupboard?” before the intervention (Pre) and after the intervention (Post).

Concerning the question “What would happen if I did not transfer the plant to a larger container when it had grown?” the responses (Figure 9) are diverse, with only a few indicating that space constraints do not necessarily impede the plant’s growth, although they might lead to issues like “breaking the container” or “the plant breaking”. Other responses suggest that limited space indeed hinders the plant’s ability to grow.

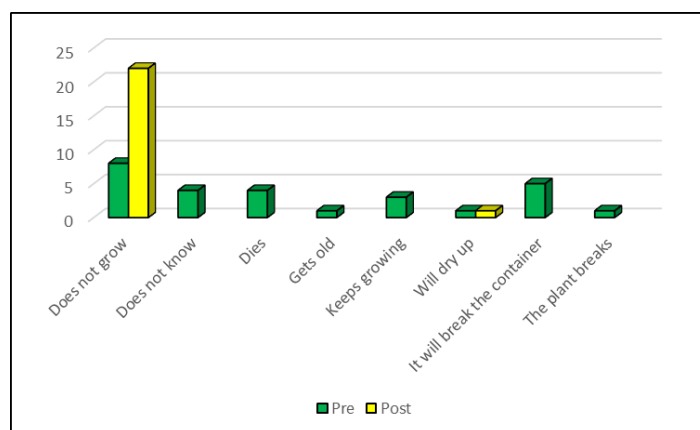


Figure 9. Responses to the question “What would happen if I did not change the container to a larger one when the plant had grown?” before the intervention (Pre) and after the intervention (Post).

4.3. At the Investigative Stage

In the experimental stage, the data obtained are interpreted following the phases of the inquiry.

4.3.1. Problem and Hypothesis Statement

After the interview, the pupils were shown the bean and lentil seeds, and a group activation question was posed: “Do you think that if we plant lentils and beans, a plant will grow? What does it need to grow?”

From the responses to this question, as well as the individual interviews and the answers obtained during the contextualization stage, hypotheses were formulated. It became evident, albeit unintentionally, that the pupils recognized that plant growth depends on factors such as water, light, and soil. Some students, however, believed it depended only on water and not on light. Interestingly, a minority of responses touched upon an attitudinal aspect related to environmental stewardship and valuing living beings. In a few cases, energy (heat) and organic matter (fertilizer) were also mentioned. Consequently, the research question was formulated as follows: “On which factors does plant growth depend, and how do these factors influence the plant?” The hypotheses derived from this were closely aligned with the preconceptions of 6–7-year-old pupils, such as the need for water, soil, and light [42].

4.3.2. Experimental Design

The experimental stage consisted of two phases: germination in cotton and subsequent growth in pots. During both phases, the teacher engaged the students with questions that fostered argumentative discourse.

First Phase: In most of the cups, germination occurred, with bean seeds exhibiting more growth. An assembly was conducted with a group question regarding the potential reasons for the non-germination of the beans. The majority of answers indicated a lack of knowledge about the cause, but some suggested possibilities such as being indoors, insufficient water, poor-quality cotton, and an excessive number of seeds in each cup. The latter two suggestions were considered new hypotheses. To validate the scientific accuracy of these answers, the students were asked to observe and examine all the vessels, both germinated and non-germinated. They discovered germinated vessels in both light and dark conditions. Consequently, when asked whether the presence or absence of light significantly influenced germination, the unanimous response was no. Regarding the quality of the cotton, the teacher showed them the original packaging from which the cotton pieces were obtained for each cup. The students, once again, did not observe any differences in the fabric and unanimously stated so. Likewise, they examined the number of seeds per beaker and found germinated beakers with a large number of seeds. When asked

as a group whether these factors influenced germination, they concluded that germination was not dependent on the presence of light, the number of seeds per beaker, or the type of cotton. This process resulted in the refutation of the previously proposed hypotheses (closed environment, cotton quality, and number of seeds).

To explore potential causes for the absence of germination in some cups, the students were asked to closely inspect the non-germinated cups and compare them with some of the germinated cups. Differences were noted, such as the cotton wool being very wet in some of the non-germinated cups, while in the germinated ones, it was almost dry or slightly moist. They also observed seeds that were outside the cotton balls. During the assembly discussion, they concluded that excess water hinders germination, and improper seed placement between the cotton balls hinders it as well. The reasons for non-germination in some cups were attributed to procedural errors, including overwatering, in which some students did not take into account the teacher's instructions, and the lack of motor skills among certain pupils, typical of their age, may have caused incorrect seed placement in the cotton wool.

Before proceeding to the next phase, the teacher gathered oral responses to the question, "How can temperature affect plants?" The students related heat to plant growth and the development of flowers and fruit, while cold was linked to freezing and damage to plants. These responses indirectly suggested that energy was necessary for plant functions.

Second Phase: In this phase, the students transplanted the germinated seeds according to the teacher's instructions. The seeds were planted approximately halfway down the glass, and the students chose which ones to water and which ones to leave in the light. Although it might have been interesting to allow the students to bury the seeds at their discretion, this was discarded as it would have made the experiment excessively lengthy.

4.3.3. Data Collection and Representation

During the measurement phase, the students realized that a centimeter ruler was required to measure the plant and its parts in centimeters. However, it was noted that for the trees in the courtyard, this ruler would not be suitable due to the small units used to measure the plants.

In addition to the notes made in their notebooks, in the third week of planting in pots, the students created cards with detailed information about the plants (Figure 10).

4.3.4. Students' Analysis, Discussion of Results, and Conclusions

Regarding the question of whether plants are living beings, the students do not question whether plants are indeed living beings. However, they display strong zoocentrism and anthropocentrism in their answers. They attribute characteristics of animals to plants (such as "drinking", "eating", "it breathes like animals", and "it breathes like humans") or even anthropomorphize them (assimilating seeds with pregnancy), which is a common characteristic among students of this age [43]. This tendency towards zoocentrism, showing a tendency to overlook plants, aligns with the findings of Amprazis and Papadopoulou [43]. It is important to note that further data are needed to confirm this observation.

In a group discussion, the results of the experiment are deliberated. The students are asked about what plants require, which parts of the plant they have identified, which ones they observed first, the color of these parts, factors that can impede plant growth, signs that indicate improper growth, what they found most fascinating about the experiment, and which stages presented the most challenges. The answers provided demonstrate scientific coherence, correctly addressing the impact of factors (water, light, soil, suitable container) on plant growth. They have accurately identified the plant's components (root, stem, and leaves) and recognized various stages and processes in the plant's growth. They can identify characteristics that signal problems in the plant's development, such as the yellow color of leaves and their fragile, dry texture.


Plant type	lentejas y alubias
Seedtime	14 de marzo - 2019
Irrigation	cada dos días
Birthdate	18 de marzo - 2019
Size -1st week -2nd week	6 centímetros 16 centímetros
Characteristics and drawing	<p>Es un poco grande y verde tiene el cholla fino y tierno y bajo</p> 

Figure 10. Example of one of the data collection sheets (drawing and handwritten texts are original and made by students participating in the intervention).

Regarding what intrigued them the most, there is unanimous agreement that observing the germination and growth of the plant through its different parts was the most captivating aspect. As for the most challenging aspects, there is also unanimity in that correctly placing the seed in the cotton wool and later in the pot, as well as accurately watering the plant, presented difficulties. It is evident that procedural aspects were the most challenging for them, while conceptual aspects, such as understanding the functions of the plant, did not seem to pose a problem. From the teacher's perspective, she notes difficulties in watering and observing differences, particularly at the initial stages when changes are not visible to the naked eye, in addition to challenges in collecting information. Other noteworthy challenges include organizing within groups, which led to resistance to making group decisions, and viewing the plants as a collective responsibility rather than assuming individual ownership.

The students are also asked whether they believe the initial questions have been answered, i.e., whether they believe the hypotheses have been confirmed. Unanimously, they answer in the affirmative: they have discovered that plants require water and light. Regarding the soil, they do not exhibit particular interest, nor do they consider that external nutrients are provided to the seed during the seedling stage, whereas in the pot, it is the soil that provides them. The students' ability to verify and deduce from observations and evidence is evident, as is their ability to present arguments to solve potential problems, such as a lack of light or water.

4.4. In the Evaluative Stage

At the end of the activity, an individual interview was conducted once again with the same questions that were asked at the beginning of the activity to compare the responses at both pre- and post-stages.

In response to the question “Where does a plant come from?” at the post-interview (Figure 2), all pupils answer that it originates from a seed. The responses are more precise than in the pre-interview. In the pre-interview, the answers indicated some confusion regarding what was expected, with some answers having a spatial sense (“from the soil,” “from the garden”). One answer was scientifically imprecise (“from the root”), suggesting that the student may not have been clear that the root is part of the plant. Moreover, the student did not consider the seed as the stage before the root in the plant’s development. The unanimous correct answers in the post-interview indicate that the students have comprehended the evolutionary process in the plant’s development. This verifies that the activity has had a positive impact on learning the content related to the parts and functions of plants.

In response to the question “What will happen in a few days if we plant a seed (beans and lentils) without water and light?” there is a clear change compared to the pre-interview responses when students seemed to consider that germination was independent of factors like water and light. In the post-interview (Figure 3), all responses concur that it is an impediment to germination. The majority of pupils state that the seed “does not grow”, an idea that, though scientifically imprecise, can be considered correct. For students in the first year of primary school, the dormant state of the seed, isolated from external stimuli, may imply a lack of growth. Another response is that it ‘dries out’, in which the student seems to connect germination and the seed’s integrity with the presence of water. Other responses, almost as abundant as the first, suggest that the seed “dies”. This indicates a lack of understanding of the concept of the seed, which has reserves to withstand adverse conditions. Except under extreme or destructive circumstances, the seed maintains its capacity to regenerate.

Following the previous question, the question “What if we water it?” is unanimously answered in the post-interview (Figure 4), where students emphasize that the development of the seed depends on the presence of water. Although the expression “it will grow” is more scientifically accurate compared to the more generic answer “a plant grows” in the pre-survey, they still do not specify that the seed does not grow, but it germinates, and then the plant grows.

Continuing the discussion on irrigation, the responses in the post-interview to the question “What if we do not water it?” (Figure 5) closely resembles the question “What will happen in a few days if we plant a seed (beans and lentils) without watering it and without light?” In the post-interview, all of them unanimously agreed that the absence of water does not benefit the seed. There is more unanimity in the answers than in the pre-interview, with the majority of answers being “it does not grow”, which, as mentioned earlier, is not the most accurate expression from a scientific standpoint. A conceptual error or confusion is observed in the term “grow” because the seed does not change substantially in size, yet they are referring to the development of the plant’s parts. Regardless of the colloquial and scientific language interference, the answers can be considered the acquisition or assimilation of knowledge close to scientific reality. The term “grow” implies a sequence of processes related to the functions of reproduction and nutrition. Regarding other responses, such as “dries up” and “dies”, comments have already been made in the paragraph on post-interview responses to the question “What will happen in a few days if we plant a seed (beans and lentils) without watering and light?”

Regarding the answers to the question “What will happen if we water it every day?” (Figure 6), the students are more categorical and concise than in the pre-interview. Most of the students answer that the plant “dies” due to overwatering, while the rest answer that it “drowns”. Both responses show a certain level of anthropocentrism. However, there is a change compared to the pre-interview, as in that moment, there were more answers that considered that the seed would not “grow,” but they also believed it would not be

negatively affected. In the post-interview, the responses imply a more negative outcome for the seed, suggesting a fatalistic ending. Conceptually, the students provide an explanation for the proposed situation that is very close to the idea of putrefaction (“it rots”). None of the students suggested the possibility of making a hole in the container to prevent the seed from “drowning”.

In response to the question “What will happen if we place a plant in the window with light when it has germinated?” there is unanimity in the answers (Figure 7). As in the pre-interview, students believe that the plant grows with light, interpreting light as a factor influencing the development of the plant.

For the question “What if it is in the dark inside a cupboard?” the post-interview responses (Figure 8) are less varied compared to the pre-interview. The answers share similar considerations as those analyzed for the absence of irrigation. The students reiterate certain anthropocentrism in their responses, confusion between “growing” and “developing”, and the attribution of light properties that do not actually influence germination.

The students assume with greater certainty that the situation is detrimental to the plant. However, the significant increase in anthropocentrism-influenced responses (“it does not breathe”) suggests that the students are actually thinking of the cupboard as an enclosed space, with the problem for the plant being the supposed lack of air rather than the absence of light. In relation to changing the container after germination, the answers (Figure 9) are almost unanimous and categorical in stating that the plant will not grow, eliminating other more imprecise or incorrect answers provided in the pre-interview. The intervention has facilitated a better assimilation of content related to the function of nutrition. However, the expression “it will not grow” is not strictly accurate from a scientific point of view, as the plant will attempt to continue its development in any way it can. Nevertheless, it conveys the idea of a sequential process, assuming plant growth as something linear that halts when there is a physical obstacle.

It is noted that there is difficulty in linking growth to more than one variable. Logical thinking leads students to answer that those with light grow without specifying “toward the light”, failing to connect the relationship between function and the directionality of tropism. They relate water to growth, but in the context of nutrition, without discussing the soil or its role as a source of nutrients.

A four-dimensional representation of the competences acquired as a demonstration of the intervention’s usefulness is presented (Table 1):

- Contents for the first level of primary education were extracted and adapted to the intervention according to the official curriculum [40] in force at the time of the intervention.
- The achievements attained according to the stated curriculum are in line with the objectives set by the curriculum and have contributed to the acquisition of basic competences in science and technology.
- The actions carried out related to the scientific procedures involved in the inquiry strategy, indicating whether they were actions carried out directly by the students (A) or actions guided through the teacher (P).
- The stages of inquiry involved.

Table 1. Summary of the development and outcome of the intervention, where the phases of the experiment are linked to the inquiry approach, presenting the objectives (expected achievements) regarding the development of scientific knowledge (actions carried out).

Contents	Expected Achievements	Actions Carried Out	Stage of the Inquiry Involved	Guided (P)	Autonomous (A)
Initiation of scientific activity and an experimental approach to some questions related to natural sciences	Carries out simple experiments and small investigations, posing problems, stating hypotheses, selecting the necessary material, carrying them out, drawing conclusions, and communicating the results.	Planting seeds in cotton. Transplanting. Identify variables. Make assumptions (ind.) Systematically collect data. Argue decisions and answers to questions. Express ideas and proposals orally.	Problem statement. Identification of hypotheses. Design of experiment. Data collection. Interpretation of results. Conclusions. Communication.	X	X
Individual and group work	Shows autonomy in planning and executing actions and tasks and takes initiative in decision-making.	Seek evidence of expected and unexpected outcomes. Choose growing conditions. Analyze the results and draw conclusions based on the analysis obtained.			X
Living things: characteristics, differentiation, observation, and recognition in the immediate environment	Directly observes and identifies plants. Identifies the parts of a plant and the function of each part.	Describe observations on germination and plant growth. Observe seeds and plants. Orally express answers on morphology and function relationships.	Data collection.		X
	Observes and records processes associated with the life of living things	Measuring the size of plant parts, the number of leaves, etc. Represent the data obtained. Describe observations.	Data collection. Representation.		X
Habits of respect and care for living beings	Displays respectful and caring behavior towards living beings	Planting, watering, and transplanting.	Experimental design. Data collection.	X	X

On the other hand, the teacher faced some challenges. The primary difficulty expressed by the pre-service teacher was related to organizing and managing the students' behavior. It appeared that the students were quite excited and nervous about an unfamiliar type of activity, unsure of how to conduct themselves in group activities, share materials, and grasp the concept that the samples belonged to the group rather than an individual. However, the teacher managed to overcome these difficulties through effective guidance and open dialogue with the students. Any initial uncertainty regarding the application of an unfamiliar methodology was swiftly resolved without any issues from the beginning of the intervention.

5. Discussion and Conclusions

The interpretation of the results enables us to explore the performance of a pre-service teacher when applying inquiry strategies in a primary education setting where traditional transmissive methods are commonly employed for teaching natural sciences.

The discussion will commence by examining how the students responded to the questions posed by the pre-service teacher regarding the germination and growth of plants both before and after the implementation of the inquiry strategy. Subsequently, we will delve into a discussion on how the pre-service teacher executed the delivery of content within the framework of inquiry, addressing any challenges encountered and offering suggestions for improvement. Lastly, a synthesis and reflection will be presented.

5.1. Performance by Students

The pupils consistently maintained a participative attitude throughout the intervention. In the recorded responses, imprecise scientific language was evident, with instances of using terms like "grow" instead of "germinate", "rot" instead of "dry" or "degrade", and references to plants "drowning due to excess water", indicating age-related limitations in knowledge. However, they displayed some aptitude for scientific procedures, which notably improved after the intervention. They demonstrated proficiency in certain executive stages, such as data collection and representation, but encountered more difficulties in other scientifically complex phases, including problem statement and hypothesis formulation. In broad terms, the pupils exhibited a clear understanding of the relationship between seeds and plants, recognizing the plant's need for water and light, though some anthropocentrism persisted. Following the instructional intervention, there was noticeable improvement both in their comprehension of plant function-related content and in their active participation in the inquiry process, leading to increased confidence in their responses to the pre-service teacher's questions.

Post-intervention, many of their initial ideas, consistent with those found in the existing literature, were rectified, though some persisted. Notably, the concept of a plant as a living being remains, in alignment with Carey's [44] observation that anthropocentrism is a universal characteristic of humans, especially among school-age children. Another recurrent theme in their responses was the similarity between plant functions and the vital functions of human beings, in line with Martí's [45] findings.

In response to the question "Where does a plant come from?" a degree of essentialism is evident, linking seeds to plants through expressions such as "dying-growing", "a flower will be born", "a plant comes out", or "it grows", implying the generation of a plant. These responses also reflect a form of vitalistic causal thinking typical of this age group, aligning with children's understanding of scientific biological knowledge [42].

From these observations, it can be inferred that pupils in the first year of primary education, having transitioned from the infant stage, are capable of engaging in and managing scientific processes, often erroneously associated with older individuals closer to the formal operational stage. This confirms the hypothesis presented in this study that Inquiry-Based Science Education can be effectively applied to very young students. In this way, it can be said that one of the objectives defined in this study has been achieved: to

know the ability of first-grade primary education pupils to acquire scientific competences and the learning of natural science topics through the use of inquiry.

Therefore, it is possible at any level of primary education without hindering the learning process, as evidenced by successful outcomes even with younger pupils in early childhood education [6,8]. The pupils in this study not only achieved the conceptual and procedural objectives but also the attitudinal ones, learning to respect one another, express themselves effectively, and appreciate the natural environment. An exemplary case to consider for classroom application is the proposal and implementation of inquiry-based teaching at all primary education levels by Rosa and Ramayón [46], which has demonstrated didactic success through evaluation.

Likewise, the satisfactory result obtained by the pupils is an example for teachers at these early levels of primary education who doubt or are undecided about applying inquiry as a teaching strategy.

In this way, another of the objectives of the work is met: to suggest to the teachers that inquiry is an active and participatory methodology for teaching natural science topics to 6-year-old students.

5.2. Performance of the Pre-Service Teacher

The pre-service teacher has demonstrated her ability to guide an inquiry-based experience with pupils in the primary education stage, achieving the first objective established in this work: to find out the competence of a pre-service teacher in applying inquiry in the first year of primary education. This accomplishment is particularly commendable given that the pupils were not accustomed to working in groups but rather individually, which added a layer of complexity to collaborative teaching. Additionally, some pupils faced challenges due to their underdeveloped psychomotor skills, a common occurrence among 6-year-olds. Notably, the pre-service teacher expressed a positive outlook regarding the utilization of participatory methodology within a framework of experiential learning, where students explore, discuss, and even question established concepts. The fact that the pre-service teacher herself expressed surprise at the possibility of employing an inquiry-based methodology, especially with such young pupils, underscores the limited familiarity pre-service teachers have with this methodology and the apprehension associated with its application to such a young age group. The lack of familiarity is evident when pre-service teachers acknowledge that the principal barrier to implementing experimental activities in the classroom based on inquiry is the insufficient teacher training and limited knowledge of this teaching approach [47]. Despite this lack of familiarity, pre-service teachers themselves express a preference for using inquiry as a teaching methodology [48]. Hence, it is strongly recommended to enhance instruction and training on inquiry-based methodology for pre-service teachers. Moreover, employing inquiry as part of the didactic content in teacher training aligns with Haefner and Zembal's [49] assertion that exposing students to activities closely resembling real-world experiences enhances content learning. In this context, instructing pre-service teachers through experimentation mirrors what they will be required to teach, ensuring more comprehensive training in inquiry. A study by Benedict-Chamber, Fick, and Arias [50] and a study by Benedict-Chambers and Aram [51] supported this approach after analyzing the instruction of inquiry procedures with pre-service teachers, which led to improvements in their knowledge related to content learning and skills associated with scientific techniques and procedures. Subsequently, they observed enhancements in aspects of general pedagogy, including managing students' interest and attention, emphasizing the importance of teacher training not only in the implementation but also in the methodology of inquiry. Along these lines, Van Uum, Verhoeff, and Peeters [52] noted that teacher training in Inquiry-Based Science Education (IBSE) enhances student learning. Given this rationale, it is imperative to assert that collaborative learning facilitates science education and the development of scientific competences, as indicated by Chin [34] and Chu, Tse, and Chow [53].

Therefore, teachers should be adequately trained in both inquiry and inquiry-based instruction, strengthening their abilities in various inquiry procedures to elevate their competency levels. This assertion is substantiated by studies such as Valls-Bautista, Solé-Llussà, and Casanoves [54], which reveal that in-service primary school teachers often encounter difficulties when introducing inquiry-based activities in their classrooms. This suggests that these teachers may not have received appropriate training during their teacher education. These authors also demonstrated that inquiry-based laboratory activities enable pre-service teachers to acquire both scientific knowledge and scientific competence. Based on this assertion and in consideration of Petermann et al.'s [55] findings on teachers' beliefs related to cultivating inquiry competence, it is recommended that teacher education institutions adapt their curriculum designs to include inquiry and provide comprehensive training to pre-service teachers. Furthermore, in-service teachers have cited a lack of resources as an impediment to the implementation of inquiry-based teaching [19]. Therefore, it is crucial to address this aspect, as it directly impacts the application of the inquiry. Education administrations are advised to offer inquiry-based training courses to in-service teachers through professional development programs.

Additionally, it is essential to provide recommendations for improving the questions posed by the pre-service teacher to enhance their scientific accuracy, eliminate ambiguity, and prevent student confusion, thereby avoiding the generation of conceptual errors. The aim is to formulate questions that closely resemble scientific inquiries [56]. For example, in the question "Where does a plant come from?" it would be more precise to eliminate the anthropocentric connotation of "comes from" and substitute it with a more scientifically accurate term such as the following: "Where does it originate?"; "How does it emerge?"; "Why does it grow?"; "How does it commence?"; "How does it develop?"; etc.

Regarding the question related to watering the seed, it should specify the quantity of water used and the frequency, keeping in mind that there is a subsequent question inquiring, "What happens if it is watered every day?" The role of water (in terms of quantity), nutrients, and the function of the soil as a nutrient source (distinct from water) should be emphasized.

With regard to the impact of light, the teacher highlights the absence of light being experienced inside a cupboard. This may lead students to associate the absence of light with a closed space and, consequently, with a lack of oxygen (referred to as "air" in their vocabulary). This, in turn, might lead them to believe that the plant does not grow due to issues related to erroneous lung respiration function. Therefore, clarification is needed to discern whether the question pertains to the seed or the plant since light is not a determining factor for the seed. Additionally, questions about the processes associated with plant functions should be separated from anthropocentric concepts like drinking, dying, eating, etc.

5.3. Synthesis and Reflection

Considering the results obtained by pupils, both from the interviews and the data collected in notebooks or record sheets, and in light of the assessment criteria and learning standards outlined in the official curriculum for the first level of primary education [40], it is evident that the objectives and competences stipulated in the curriculum have been successfully achieved. Furthermore, the implementation of inquiry has allowed us to practice argumentation. Given the age group of the pupils (6 years old), the phases of argumentation were guided by the teacher, which aligns with the structured inquiry approach. Limitations in oral expression, information retrieval, hypothesis formulation, the establishment of proofs, and their justification necessitate the teacher guiding the students through a series of questions.

In this context, argumentation is grounded in causal explanations, such as "with light, the plant grows" or "without water, it dies", enabling the evaluation of explanatory models [30]. It is important to note that the concept of a model in this context differs from Schwarz et al.'s definition [57], as the model is derived from initial and final answers and

is reflected in the worksheets. Additionally, the students' explanatory models serve as abstractions pertaining to plant functions and each part of the plant. Argumentation, in this context, facilitates a comparison between the initial anthropocentric model, which involves concepts like seeing and eating, and the final models that align more closely with scientific knowledge.

However, some researchers, such as Monteiro and Jiménez-Alexandre [58] and Benedict-Chambers et al. [59], argue that at an early age, argumentative discourse can be cultivated through inquiry activities. Even Siry et al. [16] point out that students around the age of 6 already possess the ability to explore various phenomena, make predictions, observe, collect data, and use observations as evidence. We concur with these researchers that it is feasible to implement inquiry at an early age in the lower levels of primary education. When adapted appropriately, inquiry not only enhances students' understanding of scientific concepts but also fosters their argumentative skills. In addition to gaining knowledge about plants, students have developed competences such as the recognition of vital functions in living organisms, proficiency in applying scientific processes, and the cultivation of scientific work habits. The intervention has contributed to the holistic educational development of students, demonstrating that not only can inquiry be applied in the first levels of primary education, but it also promotes comprehensive educational growth.

In short, the recommendation is made to teachers, taking into account the arguments cited in this work, so that they are not afraid to apply inquiry at early levels of primary education. In this way, the third proposed objective is met, suggesting using inquiry in their classroom.

On another note, one of the challenges reported by the pre-service teacher was the complexity of organizing the class and managing student groups, as the students were anxious. This difficulty may be one of the reasons why some teachers are hesitant to use inquiry-based methods. The fear of losing control over students and concerns about disruptive behavior may lead teachers to prioritize maintaining order over fostering participatory and formative approaches. This obstacle can be overcome with continuing training programs. If the teachers know the inquiry methodology very well, they will feel more confident in the classroom and have greater competence in managing the classroom.

6. Didactic Implications

The implementation of Inquiry-Based Science Education (IBSE) has enabled students to recognize plant functions, primarily nutrition and relationships, through a process of discovery learning, as conceptualized by Bruner [60], within the framework of an investigative model [61]. Similarly, the inquiry strategy has facilitated students' familiarity with scientific procedures, encompassing activities such as observation, measurement, representation, and argumentation, all integrated within the context of a school research project. It has also promoted reflection and the ability to make decisions in situations with multiple options, such as determining which plant to water or ensuring exposure to adequate light.

This experience can be applied as a general model for teacher trainers and in-service teachers. It serves both as an informative resource for the implementation of IBSE and as a convincing illustration that this methodology is not limited solely to students with advanced cognitive and psychomotor development. Furthermore, we recommend that education administrations allocate resources to schools and design ongoing IBSE training programs. In summary, the following recommendations are made:

- Strengthen the scientific training of pre-service teachers.
- Increase or implement training in inquiry-based methodology for pre-service teachers.
- Providing resources to schools for the development of scientific content.
- Implement in-service training programs for in-service teachers using an inquiry-based methodology.
- Combining IBSE with collaborative learning.
- Encourage primary education teachers to apply inquiry as a teaching strategy.

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References

1. Available online: <https://www.deseco.ch/bfs/deseco/en/index/03/02.parsys.78532.downloadList.94248.DownloadFile.tmp/2005.dsceexecutivesummary.sp.pdf> (accessed on 24 December 2023).
2. Sanmartí, N.; Marchán, I. La educación científica del siglo XXI. *Investig. Y Cienc.* **2015**, *82*, 31–39.
3. Rivero, A.; Martín del Pozo, R.; Solís, R.; Azcárate, P.; Porlán, R. Cambio del conocimiento sobre la enseñanza de las ciencias de futuros maestros. *Enseñanza De Las Cienc.* **2017**, *35*, 29–52. [[CrossRef](#)]
4. National Research Council. *National Science Education Standards*; National Academy Press: Washington, WA, USA, 1996; pp. 11–63. [[CrossRef](#)]
5. Ministerio de Educación. *Educación Científica “Ahora”: El Informe Rocard*; Servicio de Publicaciones: Madrid, Spain, 2009; pp. 9–78.
6. OECD. *PISA for Development Assessment and Analytical Framework: Reading, Mathematics and Science*; OECD Publishing: Paris, France, 2018. [[CrossRef](#)]
7. COSCE. *Informe ENCIENDE, Enseñanza de las Ciencias en la Didáctica Escolar Para Edades Tempranas en España*; Confederación de Sociedades Científicas de España: Madrid, Spain, 2011; Available online: https://www.cosce.org/pdf/Informe_ENCIENDE.pdf (accessed on 24 December 2023).
8. Garritz, A. Indagación: Las habilidades para desarrollarla y promover el aprendizaje [Inquiry: Abilities to develop it and promote learning]. *Educ. Quím.* **2010**, *21*, 106–110. [[CrossRef](#)]
9. Lazonder, A.W.; Harmsen, R. Meta-Analysis of Inquiry-Based Learning Effects of Guidance. *Rev. Educ. Res.* **2016**, *20*, 1–38. [[CrossRef](#)]
10. Osborne, J. Teaching scientific practices: Meeting the challenge of change. *J. Sci. Teach. Educ.* **2014**, *25*, 177–196. [[CrossRef](#)]
11. Pedaste, M.; Mäeots, M.; Siiman, L.A.; Ton de Jong, A.N.; van Riesen, S.; Kamp, E.T.; Manoli, C.; Zacharia, Z.; Tsourlidaki, E. Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educ. Res. Rev.* **2015**, *14*, 47–61. [[CrossRef](#)]
12. Romero-Ariza, M. El aprendizaje por indagación: Existen suficientes evidencias sobre sus beneficios en la enseñanza de las ciencias? *Rev. Eureka Ens. Div. Cienc.* **2017**, *14*, 286–299. Available online: <https://rodin.uca.es/handle/10498/19218> (accessed on 24 December 2023). [[CrossRef](#)]
13. Calo, N.; García-Rodeja, I.; Sesto, V. Construyendo conceptos sobre electricidad en infantil mediante actividades de indagación. *Ens. Cienc.* **2021**, *39*, 223–240. [[CrossRef](#)]
14. Piekny, J.; Grube, D.; Maehler, C. The Development of Experimentation and Evidence Evaluation Skills at Preschool Age. *Int. J. Sci. Educ.* **2014**, *36*, 334–354. [[CrossRef](#)]
15. Rodríguez Melero, A.M.; Cáceres Ruiz, M.J.; Franco-Mariscal, A.J. Cómo hacemos crecer una planta? Una indagación con niños de 3 años de educación infantil. *Ens. Cienc.* **2021**, *39*, 231–253. [[CrossRef](#)]
16. Siry, C.; Ziegler, G.; Max, C. Doing science through discourse-in-interaction: Young children’s science investigations at the early childhood level. *Sci. Educ.* **2012**, *96*, 311–326. [[CrossRef](#)]
17. Solé-Llussà, A.; Aguilar, D.; Ibáñez, M.; Coiduras, J.L. Análisis de la comunicación de experiencias indagadoras presentadas en congresos de ciencia dirigidos a alumnos de educación infantil y primaria. *Rev. Eureka Ens. Div. Cienc.* **2018**, *15*, 1302. [[CrossRef](#)]

18. Romero-Ariza, M.; Quesada, A.; Abril, A.M.; Sorensen, P.; Oliver, M.C. Highly Recommended and Poorly Used: English and Spanish Science Teachers' Views of Inquiry-based Learning (IBL) and its Enactment. *Eurasia J. Math. Sci. Tech. Educ.* **2020**, *16*, em1793. [CrossRef]
19. Fang, S.C. Towards Scientific Inquiry in Secondary Earth Science Classrooms: Opportunities and Realities. *Int. J. Sci. Math. Educ.* **2021**, *19*, 771–792. [CrossRef]
20. Bebbington, A. The ability of A-level students to name plants. *J. Biol. Educ.* **2005**, *32*, 62–67. [CrossRef]
21. Mussen, P.H.; Conger, J.J.; Kagan, J. *Personality Development in the Child*; Trillas: Mexico City, Mexico, 1982; pp. 145–168.
22. Craig, G.J. *Psychological Development*; Pearson Educación: Mexico City, Mexico, 2001; pp. 273–310.
23. Ballesteros, S.; García, B. *Procesos Psicológicos Básicos*; Universitat: Madrid, Spain, 2001; pp. 76–96.
24. Lofgren, R.; Schoultz, J.; Hultman, G.; Bjorklund, L. Exploratory talk in science education: Inquiry-based learning and communicative approach in primary school. *J. Baltic Sci. Educ.* **2013**, *12*, 482–496. [CrossRef]
25. Bybee, R.W. Scientific Inquiry and Science Teaching. In *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education*; Flick, L.B., Lederman, N.G., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherlands, 2004; pp. 1–14.
26. Capps, D.K.; Crawford, B.A. Inquiry-Based Instruction and Teaching About Nature of Science: Are They Happening? *J. Sci. Teach. Educ.* **2013**, *24*, 497–526. [CrossRef]
27. Crawford, B.A. From inquiry to scientific practices in the science classroom. In *Handbook of Research on Science Education*; Lederman, N., Abell, S., Eds.; Routledge: New York, NY, USA, 2014; Volume II, pp. 515–544.
28. Lehrer, R.; Schauble, L.; Lucas, D. Supporting development of the epistemology of inquiry. *Cogn. Dev.* **2008**, *23*, 512–529. [CrossRef]
29. Lemke, J.L. *Talking Science: Language, Learning and Values*; Ablex Publishing Corporation: Norwood, MA, USA, 1990; pp. 87–97.
30. Jiménez-Aleixandre, M.P. Designing Argumentation Learning Environments. In *Argumentation in Science Education: Perspectives from Classroom-Based Research*; Erduran, S., Jiménez-Aleixandre, M.P., Eds.; Springer: New York, NY, USA, 2007; pp. 91–115.
31. Havu-Nuutinen, S.; Kervinen, A.; Uitto, A.; Laine, A.; Koliseva, A.; Pyykko, L.; Impio, P.; Aittola, T. Pre-Service and In-Service Teachers' Experiences of Inquiry-Based Primary Education. Science Teaching: A Collaborative Team Teaching Model. *J. Baltic Sci. Educ.* **2019**, *18*, 583–594. [CrossRef]
32. Song, Y. Improving primary students' collaborative problem solving competency in project-based science. Learning with productive failure instructional design in a seamless learning environment. *Educ. Tech. Res. Dev.* **2018**, *66*, 979–1008. [CrossRef]
33. Banchi, H.; Bell, R. The many levels of inquiry. *Sci. Child.* **2008**, *46*, 26–29.
34. Duran, L.B.; Duran, E. The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching. *Sci. Educ. Rev.* **2004**, *3*, 49–58.
35. Bybee, R.W. *The BSCS 5E Instructional Model and 21st Century Skills*; BSCS Science Learning: Colorado Springs, CO, USA, 2009; pp. 1–111.
36. Chin, C. Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *J. Res. Sci. Teach.* **2007**, *44*, 815–843. [CrossRef]
37. Benedict-Chambers, A.; Fortner, T. The right kind of questions. *Sci. Child.* **2019**, *56*, 50–57. [CrossRef]
38. Weber, R.P. *Basic Content Analysis*; Sage Publications: London, UK, 1990; pp. 40–69.
39. Hernández, R.; Fernández, C.; Baptista, P. *Metodología de la Investigación.*, 3rd ed.; Mc Graw Hill: Mexico City, Mexico, 2003; pp. 121–156.
40. BOCYL. Decreto 26/2016, de 21 de julio, por el que se establece el currículo y se regula la implantación, evaluación y desarrollo de la Educación Primaria en la Comunidad de Castilla y León. *Boletín Oficial de Castilla y León* **2016**, *142*, 34184–34746.
41. Balding, M.; Williams, K. Plant blindness and the implications for plant conservation. *Cons. Biol.* **2016**, *30*, 1192–1199. [CrossRef]
42. Inagaki, K.; Hatano, G. Vitalistic causality in young children's naive biology. *Trends Cogn. Sci.* **2004**, *8*, 356–362. [CrossRef] [PubMed]
43. Amprazis, A.; Papadopoulou, P. Primary school curriculum contributing to plant blindness: Assessment through the biodiversity perspective. *Adv. Ecol. Env. Res.* **2018**, *3*, 238–256.
44. Carey, S. *Conceptual Change in Childhood*; MIT Press: Cambridge, UK, 1985; pp. 89–138.
45. Martí, J. *Aprender Ciencias en la Educación Primaria*; Graó: Barcelona, Spain, 2012; pp. 131–142.
46. Rosa, S.M.; Ramayón, M.J. Promoviendo las habilidades de indagación en la escuela primaria: Análisis de una propuesta para hacer ciencia en el aula y su evaluación mediante rúbricas. *Rev. Eureka Ens. Div. Cienc.* **2023**, *20*, 3204. [CrossRef]
47. Godoy, A.V.; Segarra, C.I.; Di Mauro, M.F. Una experiencia de formación docente en el área de Ciencias Naturales basada en la indagación escolar [A prospective teacher training experience in science based on an inquiry approach]. *Rev. Eureka Ens. Div. Cienc.* **2014**, *11*, 381–397. Available online: <http://hdl.handle.net/10498/16590> (accessed on 24 December 2023). [CrossRef]
48. Tierno, S.P.; Solbes, J.; Gavidia, V.; Tuzón, P. Scientific and didactic training for the Degree in Primary Education and the presence of inquiry according to teacher educators. *Mag. Interuniv. Form. Prof. Rifop.* **2022**, *97*, 143–162.
49. Haefner, L.A.; Zembal, C. Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *Int. J. Sci. Educ.* **2004**, *26*, 1653–1674. [CrossRef]
50. Benedict-Chambers, A.; Fick, S.J.; Arias, A.M. Preservice Teachers' Noticing of Instances for Revision during Rehearsals: A Comparison across Three University Contexts. *J. Sci. Teach. Educ.* **2020**, *31*, 435–459. [CrossRef]

51. Benedict-Chambers, A.; Aram, R. Tools for Teacher Noticing: Helping Preservice Teachers Notice and Analyze Student Thinking and Scientific Practice Use. *J. Sci. Teach. Educ.* **2017**, *28*, 294–318. [CrossRef]
52. Van Uum, M.S.J.; Verhoeff, R.P.; Peeters, M. Inquiry-based science education: Towards a pedagogical framework for primary school teachers. *Int. J. Sci. Educ.* **2016**, *38*, 450–469. [CrossRef]
53. Chu, S.K.W.; Tse, S.K.; Chow, K. Using collaborative teaching and inquiry project-based learning to help primary school students develop information literacy and information skills. *Library Inf. Sci. Res.* **2011**, *33*, 132–143. [CrossRef]
54. Valls-Bautista, C.; Solé-LLussà, A.; Casanoves, M. Pre-service teachers' acquisition of scientific knowledge and scientific skills through inquiry-based laboratory activity. *High. Educ. Ski. Work. Based Learn.* **2021**, *11*, 1160–1179. [CrossRef]
55. Petermann, V.; Vorholzer, A. Relationship between Beliefs of Teachers about and Their Use of Explicit Instruction When Fostering Students' Scientific Inquiry Competencies. *Educ. Sci.* **2022**, *12*, 593. [CrossRef]
56. Ferrés-Gurt, C. El Reto de Plantear Preguntas Científicas Investigables. *Rev. Eureka Ens. Div. Cienc.* **2017**, *14*, 410–426. Available online: <http://hdl.handle.net/10498/19226> (accessed on 24 December 2023). [CrossRef]
57. Schwarz, C.; Reiser, B.; Davis, E.; Kenyon, L.; Acher, A.; Fortus, D.; Shwartz, Y.; Hug, B.; Krajcik, J. Developing a Learning Progression for Scientific Modeling: Making Scientific Modeling Accessible and Meaningful for Learners. *J. Res. Sci. Teach.* **2009**, *46*, 632–654. [CrossRef]
58. Monteiro, S.F.; Jiménez-Aleixandre, M.P. The practice of using evidence in kindergarten: The role of purposeful observation. *J. Res. Sci. Teaching.* **2016**, *53*, 1232–1258. [CrossRef]
59. Benedict-Chambers, A.; Kademian, S.M.; Davis, E.A.; Palincsar, A.S. Guiding students towards sensemaking: Teacher questions focused on integrating scientific practices with science content. *Intern. J. Sci. Educ.* **2017**, *39*, 1977–2001. [CrossRef]
60. Bruner, J. *El Proceso de la Educación*; Hispanoamericana: Mexico City, Mexico, 1972; pp. 61–110.
61. Hernández, A.; Yelena, A. *Didactic Models for Learning Situations and Contexts*; Narcea Ediciones: Madrid, Spain, 2017; pp. 31–56.

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