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REVIEW ARTICLE

The Understanding of Scientific Inquiry by Teachers in Initial Training: A Comparative Study between Brazilian and Portuguese Undergraduates

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ABSTRACT

Understanding the relevant aspects of the construction of knowledge in science, as well as the elements that are an essential part of a scientific inquiry, need to be discussed in teacher training courses in the area of natural sciences. This study aimed to identify and classify investigative elements present in the conceptions of undergraduates from a university in Brazil and another in Portugal who will be working in basic education. This is a qualitative study using content analysis to identify categories based on the students' responses, and a quantitative approach using descriptive statistics to quantify the absolute frequency of each response. The data were obtained during a preparatory course on inquiry teaching given to 30 undergraduates from both countries in 2023 through the analysis of a problem situation involving forensic entomology. The results showed that the most frequent investigative elements present in the students' answers are the problem, the formulation of hypotheses, the collection, analysis, and interpretation of data, and the conclusion.

KEY WORDS: Basic education; scientific inquiry; teacher training

INTRODUCTION

Today's world places great value on scientific and technological development. The terms science and scientific knowledge are frequently used and mentioned by people from different backgrounds. Science is present in many ways in the lives of citizens.

In basic education, there is a subject, in the curriculum, called "Sciences," which is part of an area of knowledge called Natural Sciences. In university courses, there are also various courses that include the term Science, such as Biological Sciences, Education Sciences, and others.

Considering that Science is a common terminology both in everyday life and in academic circles, it is necessary for undergraduates, who will be future teachers in this area, to understand its foundations and even what scientific research is. In this sense, one concept that has been highlighted in studies on teacher training is investigative competence.

Wafunga (2017) considers competences to be the knowledge needed by teachers to resolve situations specific to their role or function. Among these competencies, the author mentions investigative competences. In the field of teaching, the author states that providing the development of investigative competences is fundamental for teacher training.

According to Sosa Herrera (2023), investigative competences include knowledge, skills, and attitudes. With regard to these competences, in terms of the aspect involving knowledge, it is important for undergraduates to be clear about the fundamentals of scientific research. Gizaw and Sota (2023) carried out a literature review on available strategies for improving scientific process skills (SPS) practices. The authors argue that achieving scientific literacy requires more than simply understanding the main concepts of the content but requires the acquisition of SPS. These skills are also known as process skills, and skills for scientific inquiry.

In this sense, several studies have pointed out the conceptions of science held by teachers in initial and continuing training (Da Conceição Cruz and Veras, 2017; Baccin and Coutinho, 2018; Cortez and Kiouranis, 2019). These studies show that undergraduates have difficulties associating the term Science with its epistemological aspects, and their conceptions are related to the content taught in the subjects in the area of Natural Sciences. According to Da Conceição Cruz and Veras (2017), these mistaken views can be built up during initial training due to the emphasis placed on content to the detriment of the means of obtaining this knowledge. The authors admit the need to improve initial teacher training and broaden discussions about what Science is. Accordingly, Pérez et al. (2001) argue that in higher education students do not have the opportunity to develop and explore scientific concepts in investigative activities. This statement is corroborated by Teixeira et al. (2009) when they point out that many of the stereotypical views that teachers present are due to the lack

of opportunities for discussions about the nature of science, as well as its inherent components, to develop more appropriate conceptions about the nature of scientific work.

Undergraduates will be able to teach subjects related to the Natural Sciences in Basic Education and for this reason, it is necessary for them to know the fundamentals pertinent to the construction of scientific knowledge. In this regard, a current proposal that has addressed this perspective is "teaching by inquiry," which allows undergraduates to have contact with investigative practices during their initial training.

When it comes to investigative practices, studies have shown the results of applying these practices in teacher training programs, such as the institutional teaching initiation scholarship program and the pedagogical residency (Silva and Scarpa, 2012; Bertola and Moraes, 2021). One aspect that deserves attention when dealing with inquiry teaching is the elements that make it up, i.e., the investigative elements that are essential to a scientific inquiry.

Pedaste et al. (2015) carried out a wide-ranging literature review in order to propose a consensual framework for inquiry teaching. In summary, the authors concluded, as central elements, that inquiry teaching should provide students with the opportunity to solve problems, formulate hypotheses, collect, analyze, and interpret data, draw conclusions, communicate, and reflect on the investigative process.

Cardoso and Scarpa (2018) call these central aspects, which are part of investigative practices, as well as constituents of scientific inquiry, investigative elements, and they are problem/question, hypothesis/prediction, planning, data collection, conclusion, and future stages of the inquiry, in addition to the prioritization of evidence highlighted by De Carvalho et al. (2018).

The studies by Gizaw and Sota (2023) point to research skills such as observation, questioning, formulating hypotheses, experimenting, analyzing, and interpreting data, and drawing conclusions. Anderson (2002) states that these concepts are basic in an inquiry and, therefore, their understanding is fundamental.

Considering the need for undergraduates to know the essential elements that make up a scientific inquiry, given that they will be working on subjects involving the Natural Sciences, in this study, we have sought to answer what understanding of scientific inquiry is held by undergraduates in courses to train teachers in Basic Education. This study aims to identify and classify the investigative elements present in the students' conceptions.

To do this, the students observed and analyzed a comic book about an investigation called "The Jaguar Case," based on Forensic Entomology as proposed by Bruckelman (2013).

This study is part of a larger research project investigating the challenges and possibilities of using investigative practices with primary school students by undergraduates in teacher training courses for basic education. The project involves two Brazilian universities, a state and a federal one, and a Portuguese university.

INQUIRY PRACTICES AND TEACHER TRAINING

The construction of scientific knowledge is based on a few essential elements. Doubt/questioning is what triggers a scientific inquiry. In this sense, Bachelard (1996) states that scientific knowledge is born from questioning. To solve problems, there are paths to be taken in a scientific inquiry and, in this way, some of the main elements of an inquiry stand out, such as the perception of evidence or clues that make it possible to issue hypotheses and subsequent confrontation, obtaining and recording data, analysis and interpretation, conclusion, dissemination, and communication of results (NRC, 2000; 2012).

De Carvalho (2013) admits that there is no single scientific method; however, the author defends the presence of essential stages and reasoning in the construction of scientific knowledge, which differentiates it from common sense knowledge. Therefore, it is necessary to emphasize that knowledge of aspects involving the epistemology of science enables teachers to better understand the science to be taught, as well as helping them to reflect on and prepare learning activities that are aligned with learning about the nature of science (Praia et al., 2002).

Cutrera (2003) corroborates this idea by stating that teachers need to understand how scientists produce and use scientific knowledge, how they decide what to research, how scientific data are obtained and interpreted, and how they decide whether to accept published results. According to the author, this is knowledge about science.

Undergraduate students who are going to teach science classes in basic education, at any stage of schooling, need to have knowledge and clarity about the fundamentals of scientific research, and these practices need to be provided during their initial training.

Studies by Silva and Schnetzler (2008), Maldaner (2008), Suart and Marcondes (2018) show that undergraduate courses to train teachers in Natural Sciences still have curricula based on traditional concepts and technical rationality, and do not favor effective articulation between the academy and school practice.

According to Suart and Marcondes (2018), these courses have curricula that prioritize specific knowledge to the detriment of that necessary for teaching practice, highlighting the idea that teaching only requires knowing specific content and mastering a few techniques on how to teach. The authors emphasize the importance of the experiences undergone by undergraduates in initial training courses and state that this knowledge contributes to future teachers reproducing obsolete practices in their classes that are unsuitable for the training of basic education students, given the training demands of today's society.

METHODOLOGICAL PROCEDURES

This study is characterized as qualitative and quantitative descriptive. The research participants were undergraduates, fifteen students, six male, and nine female, attending the 4th year of the Biological Sciences course at a Brazilian university in the state of Paraná. In Portugal, fifteen students took part in the study, only one of whom was male, and they were in their 1st and 2nd years at a Portuguese university and attending the Masters course in Teacher Training for Basic Education. The students in both countries were aged between twenty and twenty-two.

The professors from both universities have a partnership for scientific cooperation and the development of a research project investigating inquiry teaching in teacher training. The undergraduates from both universities took part in a training course entitled "Teaching by Research and Applications in Classroom." According to the documents that make up the guidelines for teacher training and define essential learning in both countries, undergraduates need to have an understanding of scientific research processes during their initial training. In some subjects, investigative procedures are explored, but these are, in our opinion, insufficient. Therefore, we believe it is necessary to provide a course for undergraduates to give them contact with both the fundamentals and practices of scientific investigation.

The course was organized into three stages. The first was theoretical in nature and included three activities to assess the undergraduates' knowledge of the investigative process in science. The second stage consisted of the presentation and application of investigative activities to familiarize the undergraduates with these practices. The third stage involved the production of investigative activities by the undergraduates to be applied to primary school students. All the course activities were carried out in groups of four or five participants. The course was held in Portugal in March 2023 and in Brazil in April 2023.

In this study, we present data from the first activity entitled "The Jaguar Case," it presents a problem situation, in which a jaguar is found dead. To find out the cause of death, two experts investigated the case. In the dialog developed during the story, it is possible to observe elements that are pertinent to an inquiry, even if it is not specifically scientific research. This activity was carried out by the undergraduates on the 1st day of the course and aimed to identify their understanding of the elements that make up an inquiry. To carry out the activity, the students were organized into groups of four. The researchers who were teaching the course gave the undergraduates a sheet of paper containing the story of the investigation regarding the death of the jaguar, to which they had to indicate by looking at the images "which elements are part of an investigation." The students discussed the story in groups and produced a summary of their discussions, which was handed to the researchers.

All participants agreed to participate in the study and signed the Informed Consent Form.

DATA PRESENTATION AND ANALYSIS

The data obtained in this study were analyzed using Gomes' (2009) content analysis technique, considering the qualitative approach of the research, and descriptive statistics for the quantitative approach. The students' answers were analyzed and categorized according to Gomes (2009). According to the author, we can find various ways of analyzing the participant's message, by breaking down and treating the content obtained. The author proposes the following path for content analysis.

(a) breaking down the material to be analyzed into parts (what is a part will depend on the recording unit and the context unit we have chosen); (b) distributing the parts into categories; (c) describing the result of the categorization (setting out the findings found in the analysis); (d) interfering with the results (making use of premises accepted by the researchers); (e) interpreting the results obtained with the help of the theoretical basis adopted. (Gomes, 2009, p. 79)

According to the content analysis, the students' answers, obtained in the groups, were first read in detail in response to the question "What elements in this story are part of an investigation?" and then the context units were established, which are broader themes that emerge from the groupings obtained from the students' answers. According to Bardin (1988), this corresponds to the segment of the message, which, due to its higher dimension, allows us to understand the meaning of the record.

Based on the investigative elements pointed out by Pedaste et al. (2015), and Cardoso and Scarpa (2018), it was possible to identify, in the material collected, two types of student responses when reading the images about forensic entomology. Longer answers in which the students demonstrated an understanding of more general aspects relating to the investigation and shorter answers in which the students pointed out specific aspects involving the investigative elements. In this way, two context units were obtained which indicate the students' understanding of scientific inquiry. The context units were entitled "general aspects of the students "responses,' and "specific aspects of the students" responses." Based on these units, the respective categories were established. For the first context unit, 4 categories were listed: (A) - comparison between phenomena, (B) - observation of facts, (C) - identification of data, and (D) - conclusion of the investigation. For the second context unit, 7 categories were established: (A) - Proposing the Problem, (B) - Formulating the Hypothesis, (C) - Obtaining Data, (D) - Analyzing Data, (E) - Identifying Evidence, (F) - Conclusion, and (G) - Other terms.

The data were also analyzed using basic concepts from statistics, which is made up of a set of techniques that make it possible to organize, describe, analyze, and interpret data from a study. Statistics can be divided into three areas: descriptive statistics, probability, and inference. According to the nature of the study in this paper, basic tools from descriptive statistics were used, which can be defined as a set of techniques used

to describe and summarize data to obtain conclusions about characteristics of interest (Magalhães and Lima, 2005). In this case, the aim was to ascertain the absolute frequency of the data.

At the Portuguese university, the students worked in 4 groups, and at the Brazilian university in 5 groups. The groups at the Portuguese university are identified as 1P, 2P, 3P, 4P, and at the Brazilian university as 1B, 2B, 3B, 4B, 5B.

Table 1 shows the first context unit, with more general answers about scientific research and their respective categories. Table 2 shows the second context unit and its categories, and also brings together the synthetic answers with specific terms that are part of an investigation.

Table 1 contains verbatim excerpts from the students' answers, which made it possible to establish the context unit "general aspects of the students" answers' and 4 categories: (A) -comparison between phenomena, (B) -observation of facts, (C) - identification of data, and (D) - conclusion of the investigation.

The students' answers are shown in Chart 1, which shows the predominance of answers in each group. The horizontal axis of the chart shows the 4 categories of analysis: (A) - comparison between phenomena, (B) - observation of facts, (C) - identification of data, and (D) - conclusion of the investigation. The vertical axis shows the number of excerpts from each group relating to each of the categories analyzed. Thus, in category A, a comparison between phenomena, the Brazilian group 1B made 3 notes that fall into this category.

Regarding the students' answers, which indicate general aspects of a scientific inquiry, category A (comparison between phenomena) was only established by one Brazilian group (1B). Category B (observation of facts) was identified in all the groups, although some teams presented more than one indication of the observation of facts. This was the category with the most references. Category C (identification of data) was observed by two Brazilian groups (2B) and (3B) and two Portuguese groups (2P) and (4P), category D (conclusion of the investigation) also by two Brazilian groups (2B) and (3B), and two Portuguese groups (1P) and (4P).

In category A, the students observe that the experts compare the facts to move forward in the investigation. One of the undergraduates uses the term "infer locality." In this sense, it is important to emphasize that comparing data and facts is an aspect of research, especially when it comes to experimental work, in which there is a need for a control and experimental group. Comparison is essential in experimental studies (Gerhardt, 2009).

In category B, relating to the observation of facts, there are terms mentioned by the students such as perceiving, observing, hypothesizing, evidencing, deducing, and relating to previous knowledge. Some of these terms are characteristic of a scientific inquiry. Noticing and observing are necessary actions to trigger investigations. Evidence or clues need to be identified in order to formulate hypotheses. The National Research Council - NRC (2012) points to the perception of evidence as one of the inherent aspects of a scientific inquiry. Regarding the formulation of hypotheses, De Carvalho (2013)

Table 1: General aspects of student responses

Categories	Brazilian university (B)	Portuguese university (P)
A- Comparison between phenomena	-Correlate the stage of the life cycle with the time of the crime (1B) -Compare larval development at two points (1B) -Compare fly species to infer the crime location (1B)	
B- Observation of facts	- Trying to solve a crime (1B) - Noticing the larval stage of flies and deducing that the body has been at the crime scene for some time (2B) - Noticing the scarring several times and hypothesizing that the jaguar had been in captivity (2B) - Observing that the concentration of flies was indicative of gunshot wounds (3B) - Knowledge of the healing process indicated that the skin wound was recurring (3B) - A doctor on site analyzing and creating hypotheses through the behavior of the beetles (4B) Behavior of the beetles (4B) Life cycle showing many pupae (4B) Development of flies (4B) - The girl investigates the death of the jaguar using her prior knowledge and the elements of the text she refers to are technical and precise facts (5B)	- Observing a body (1P) - Observation (2P)(3P)(4P)
C- Data identification	- Identify the focus of larvae in the open wounds indicating 4 shots, as there is a greater quantity in the open wounds (2B). - Identify the time the body was at the scene through knowledge of the fly cycle (3B)	- Indicate the cause that led to the investigation (2P) - Search for events (4P)
D- Conclusion of the investigation	- The analysis concluded that there were remains of flies that live exclusively in urban centers (2B) - The presence of a certain species of fly that occurs in the urban area indicated that the jaguar was not in the area found, but in captivity in the city. (3B)	- Looking for more information because the previous one wasn't enough (1P) - Feedback on the results obtained (4P)

Source: Research data

Table 2: Specific aspects of the student's responses

Categories	Brazilian university (B)	Portuguese university (P)
A- Problem statement	- Problem/question to be investigated (1B)	- Problem statement (1P)(4P)
B- Hypothesis formulation	- Raising hypotheses (1B)	- Hypothesis (1P)(4P)
		- Formulating theories (3P)
C- Data collection		- Data collection (1P)(3P)(4P)
		- Sample collection (2P)
D- Data analysis	- Microscopic analysis (4B)	- Data interpretation and analysis (1P)
	- Analyzing the indices (1B)	- Sample interpretation (2P)
	- Analysis (1B)	- Data analysis (4P)
		- Analysis (3P)
E- Identifying evidence	- Proof and evidence (1B)	- Evidence and facts (3P)
F- Conclusion		- Conclusion of the data collected (1P)
G- Other terms		- Scientific names (3P)
		- Scientific literacy (3P)
		- Research (3P)
		- Cooperation (4P)

Source: Research data

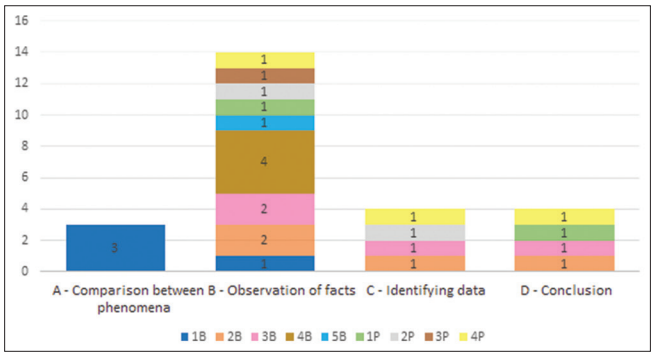

Chart 1: General aspects obtained from the students' answers about scientific research. Source: Research data

states that there are steps and reasoning that are essential in scientific inquiry, one of which is the development and testing of hypotheses. The author argues that prior knowledge should enable students to construct their hypotheses and test them in an attempt to solve the problem. About prior knowledge, Duschl (2008) points out that hypotheses can be tested even against the prevailing beliefs of individuals.

In this category, all the groups, from both the Brazilian and Portuguese universities, made references using the action verbs observe, perceive, indicate, analyze, and highlight. It should be noted that at the Portuguese university, all the groups only used the terms "observe" and "observation."

Category C is data identification. Scientific inquiries produce data that must be analyzed in order to obtain meaning. In this case, the data must be supported by a solid foundation of evidence (NRC, 2012). The last category refers to the conclusion of the investigation. This last phase of the investigation is characterized as a return to the initial problem, hypotheses, and the data obtained in the confrontation of the hypotheses to close the investigation (Pedaste et al., 2015). In this category, only groups (2B) and (3B) at the Brazilian university and (2P) and (4P) at the Portuguese university recognized and mentioned the conclusion as an element that should exist in an investigation.

According to Pedaste et al. (2015), the conclusion is the stage in which comparisons and inferences are made based on the data, hypotheses, and research question. It is not just the end of the investigation, but a resumption of its stages. Thus, in category D - Conclusion of the investigation, there were statements from groups (2B) and (3B), (1P) and (4P). The Brazilian students, groups (2B) and (3B), used the verbs conclude (2B) and indicate (3B) to refer to conclusions that could be observed from the presence of flies. A relevant aspect, in this case, is that the Portuguese students, groups (1P) and (4P), concluded that the information was not enough (1P) and mentioned the need for feedback on the results (4P).

Table 2 contains verbatim excerpts from the students' answers with more specific aspects of the investigation with its unit of context and the 7 categories of initial analysis: (A) - Proposing the problem, (B) - Formulating the hypothesis, (C) - Obtaining data, (D) - Analyzing data, (E) - Identifying evidence, (F) - Conclusion, and (G) - Other terms.

The student responses shown in Table 2 have been summarized in Chart 2, which shows the analysis categories on the horizontal axis: (A) - Problem proposal, (B) - Hypothesis formulation, (C) - Data collection, (D) - Data analysis, (E) - Identifying evidence, (F) - Conclusion, and (G) - Other terms, and the number of excerpts for each of the categories on the horizontal axis. In category A - Problem proposal, there were two excerpts from group 2B, 1 from group 1P, and 1 from group 4P.

Regarding the specific aspects pertinent to an inquiry, from the students' answers A - Problem Proposal, only one Brazilian group (2B) and two Portuguese groups (1P) and (4P) referred to the problem proposal. As for category B Hypothesis Formulation, one Brazilian group (1B) and three Portuguese

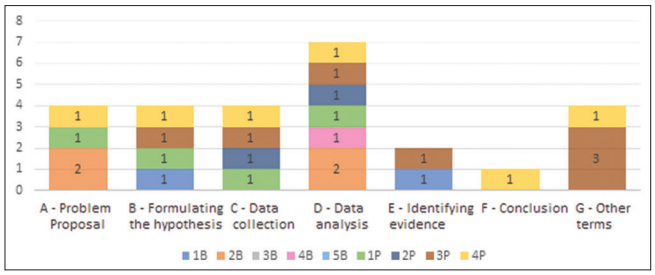

Chart 2: Specific aspects of the students' responses regarding the scientific inquiry. Source: Research data

groups (1P), (3P), and (4P) indicated something related to the hypotheses. When it came to Data Collection, category C, only the Portuguese groups (1P, 2P, 3P, and 4P) referred to the data. Category D, data analysis, was the one with the highest frequency of groups, indicating data analysis of the excerpts from the students' answers. Category E (Identifying evidence) was covered by one Brazilian group (1B) and one Portuguese group (3P). Conclusion, category F, was referenced by only one Portuguese group (4P). Category G, Other Terms, included terms mentioned in the answers that did not specifically refer to investigative elements. Two Portuguese groups appeared in this category (3P) and (4P).

The Portuguese group (4P) covered 6 of the 7 categories established in the recording unit entitled "specific aspects of the student's responses," and the Brazilian group (2B) covered the most categories. The Brazilian group (5B) only indicated more general aspects of an investigation in their answers and were therefore only included in the first context unit indicated in Table 1, referring to category B.

Brazilian and Portuguese undergraduates referred to the problem proposal (category A). The Brazilian group (1B) referred to the problem or doubt of the issue to be investigated and the case under study. Groups (1P) and (4P) from the Portuguese university referred to the problem question. Hypothesis formulation (category B) was related by one Brazilian group (1B), which referred to raising hypotheses, and three Portuguese groups, two groups (1P) and (4P), referred to the hypothesis, and the group (3P) to the theory formulation. Data collection (category C) was only indicated by the Portuguese undergraduates, groups (1P), (3P), and (4P) indicated data collection, and group (2P) sample collection. Data analysis (category D) was observed by both Brazilian and Portuguese undergraduates. The Brazilian students used the verb analyze (1B) and the noun analysis (4B) and (1B). The Portuguese undergraduate students also used the noun analysis (3P), (4P), and (1P) the noun interpretation. As for category E (identifying evidence), the Brazilian group (1B) referred to proof and evidence, and the Portuguese group (3P) referred to proof and facts. Only one Portuguese team (1P) referred to the conclusion (category F). The Portuguese undergraduates also referred to other terms (category G), such as scientific names (3P), scientific literacy (3P), research (3P), and cooperation (4P).

DISCUSSIONS AND CONCLUSION

From the answers and results presented, it is possible to notice that the Brazilian students understood the more general aspects of the investigation and tried to reproduce in detail the actions of the experts they saw in the images presented. In this sense, Table 1 shows 17 answers from the Brazilian students, which point to a more general view of the investigation, and only 6 answers from the Portuguese students.

Regarding the more specific aspects presented in the students' responses, there were 6 responses from Brazilian students and 15 from Portuguese students, as shown in Table 2. It is important to highlight that these more specific aspects classified in Table 2 correspond to the investigative elements proposed by Pedaste et al. (2015), and Cardoso and Scarpa (2018), except for the category named "other terms."

Observing facts was the category that gathered the most responses. All the groups pointed to this element as part of a scientific inquiry, as well as data analysis, which makes up category D of the specific aspect's context unit in the students' responses. The investigative elements mentioned by Pedaste et al. (2015), and Cardoso and Scarpa (2018), as well as the SPS proposed by Gizaw and Sota (2023) that are present in the student's answers, are the problem, the hypothesis formulation, data collection, analysis and interpretation, and conclusion.

The problem, hypothesis formulation, data collection, and analysis were mostly mentioned by Portuguese students. The conclusion was mentioned by two Brazilian and two Portuguese groups. The perception of evidence, which is essential to scientific inquiry, according to De Carvalho (2018), was only highlighted by groups 1B and 3P. In this sense, it is possible to infer that the Portuguese students are clearer about the elements that make up a scientific inquiry.

Tsoumanis et al. (2023) point out that scientific literacy has been the ultimate goal of scientific education around the world to develop investigative skills in individuals to face the challenges of the modern world. In a study carried out by the aforementioned authors on scientific literacy in Greek teachers in initial training, they indicate that the undergraduates had a satisfactory understanding of the identification of questions that can be answered through scientific inquiry, as well as demonstrating an understanding that the conclusion must be formulated based on evidence. Despite some positive results regarding the scientific literacy of teachers, Millar (2003) points out that there is evidence that many students and adults have little understanding of basic ideas or processes in science. In this regard, Heredia et al. (2023) point out that preparation for the development of investigative skills has not been prioritized in basic education, so students enter higher education without this knowledge and ability. It is, therefore, essential to change the curricula and programs of some subjects in teacher training courses. However, for this to happen, we also believe it is necessary to invest in the training of university professors, as they need training and professional development

to be able to effectively implement inquiry teaching with their students. Encouraging other research projects on this subject could provide more data to help reinforce this need.

Although inquiry teaching can present some implementation difficulties, it is important to notice that these can be overcome with proper planning, the necessary support, and adaptation to the specific needs of the students and their circumstances. This pedagogical approach offers numerous benefits for the development of critical thinking skills, problem-solving, and autonomous learning.

In this sense, we agree with Heredia et al. (2023), who propose programs to teach inquiry practices so that students develop investigative competence and highlight the need for teacher training courses; here we emphasize the area of Nature Sciences, to provide moments that lead them to discuss and reflect on scientific inquiry.

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