Science, Education and Innovations in the Context of Modern Problems
Issue 12, Vol. 8, 2025

Title of research article

Revisiting Inquiry Through Historical Narratives: A Comparative Analysis of Brazilian and Portuguese Undergraduate Conceptions on Investigative Science Teaching Using the Case of Puerperal Fever

Andreia de Freitas Zompero
PhD in Science Education,
Universidade Estadual de Londrina, Londrina
Brazil
ORCID: https://orcid.org/0000-0002-5123-8073 | E-mail: andreiazomp@uel.br

Tania Aparecida da Silva Klein
PhD in Science Education
Universidade Estadual de Londrina, Londrina
Brazil
ORCID: https://orcid.org/0000-0002-0137-0973 | E-mail: taniaklein@uel.br

Vinícius Ferreira Lourenço
Doctor of Science in Education,
Universidade Estadual de Londrina, Londrina
Brazil
ORCID: https://orcid.org/0009-0007-4697-7289 | E-mail: vinicius.lourenco@uel.br

Isilda Teixeira Rodrigues
Doctor of Education
Universidade Trás-os-Montes e Alto Douro-Portugal
Portugal
E-mail: ORCID: https://orcid.org/0000-0002-6020-5767 | E-mail: isilda@utad.pt

Issue web link https://imcra-az.org/archive/387-science-education-and-innovations-in-the-context-of-modern-problems-issue-12-vol-8-2025.html

Keywords History of Science; Inquiry-Based Science Education; Investigative Practices; Teacher Training; Science Teaching; Puerperal Fever; Comparative Study

Abstract
Investigative practices have been recognized as central to meaningful science education since the late nineteenth century. Contemporary approaches emphasize inquiry-based learning as a pedagogical strategy capable of promoting a deeper understanding of how scientific knowledge is generated, validated, and transformed. Within this context, the History of Science (HoS) has increasingly been incorporated into science teaching as a means to contextualize epistemic practices and expose students to real scientific controversies, uncertainties, and methodological processes. This study investigates how undergraduate students from Brazil and Portugal identify and interpret investigative elements when engaging with a historical narrative about the discovery of puerperal fever. Using a qualitative design, data were collected from Biological Sciences undergraduates at a Brazilian public university and master's students in a Teacher Training program in Portugal. Thematic analysis showed that students readily recognized problem posing, hypothesis generation, observation, and experimentation, while demonstrating less awareness of data analysis, evidence evaluation, and epistemic justification. The results highlight challenges in integrating historical case studies into inquiry-based teaching and call for improved teacher education approaches.

Citation. Zompero, A. de F., Klein, T. A. da S., Lourenço, V. F., & Rodrigues, I. T. (2025). *Revisiting inquiry through historical narratives: A comparative analysis of Brazilian and Portuguese undergraduate conceptions on investigative science teaching using the case of puerperal fever*. **Science, Education and Innovations in the Context of Modern Problems, 8**(12), 1174–1189. https://doi.org/10.56334/sei/8.12.96

Received: 19.03.2025	Accepted: 27.09.2025	Published: 11.11.2025 (available online)

1. Introduction

The use of investigative practices in science classes has been encouraged since the end of the 19th century (DeBoer, 2006). At the beginning of the 20th century, with the studies of Dewey and Joseph Schuwab, there was an increase in the inclusion of investigative practices in the curricula of subjects involving Science Education.

Teaching by investigation, inquiry, inquest - these are all names for the same teaching approach, which aims to help students understand the process of building scientific knowledge through activities that include elements of scientific investigation in their structure. In this sense, this teaching perspective, by promoting student reflection, argumentation, logical reasoning, and understanding of the fundamentals of scientific knowledge construction, is in line with the demands and training requirements for living in contemporary society. In a world full of constant changes in the most diverse areas, understanding science and its foundations is extremely important for citizen education.

Studies by Villareal et al. (2012), Salazar et al. (2019), and Barboza (2021) show that the use of investigative practices in teaching encourages primary school students to develop the cognitive skills required for scientific investigation, such as identifying a problem, formulating and confronting hypotheses, taking and interpreting data, perceiving evidence, and drawing conclusions. However, for these practices to be successfully applied in the classroom, it is necessary to think first and foremost about the need to bring about an understanding of them at the very foundation, i.e. in the initial training of teachers.

However, before undergraduates learn how to carry out activities such as investigative practices, they need to understand the principles of a scientific investigation as well as the essential elements that make it up.

The creation of scientific knowledge is based on some of these elements. Doubt/questioning is what triggers a scientific investigation. To solve problems, there are paths to be taken in a scientific investigation and, in this way, some of the main elements of an investigation stand out, such as the formulation of hypotheses, 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).

In this sense, Cultrera (2003) emphasizes the need for teachers to understand how scientists produce and use scientific knowledge, how they decide what to research, how scientific data is obtained and interpreted, and how they decide whether to accept published results. In this way, it can be said that this knowledge is related to 'learning about science' (Hodson, 2014).

Regarding learning about science, Scarpa & Campos (2018) argue that the objectives of science teaching today have come to prioritize knowledge about how concepts and theories are constructed, enabling students to understand the characteristics of scientific research as well as the difficulties faced by scientists in the research process. Concerning these aspects of learning about science, Hodson (2014) states that an important aspect of learning science is knowing and understanding the history and development of scientific ideas, and the social and intellectual circumstances surrounding their development.

Authors such as Matthews (1995), Vannucchi (1996), and Martins and Brito (2006) also recognize the importance of the History and Philosophy of Science in Science Teaching, because, according to the authors, they provide support for learning scientific theories as well as providing relevant discussions about the nature of scientific knowledge, contributing to a better understanding of various aspects relating to the Nature of Science, such as the relationship between Science and Society, and the perception of Science as a human activity (Ortiz & Silva, 2016).

According to many authors, the teaching of science still translates into an overvaluation of science content and, conversely, a devaluation, or even omission, of the history of science and the nature of science (Cachapuz et al., 2000; Rodrigues, 2019). As Duarte (2003) makes clear, the weak impact at different levels of the teaching-learning process when trying to promote the History of Science on the quality of teaching and student learning, one of the main challenges is teacher training. According to Duarte (2004), the use of the History of Science in science teaching brings teacher training to the center of educational problems.

The History of Science is already part of the Portuguese National Curriculum, although it is limited to a 'minimalist interpretation,' i.e., which advocates the inclusion of some historical material, such as biographies, descriptions of the opinions of former scientists, and important episodes in the History of Science, in some subject content (Duarte, 2003). In Brazil, according to the National Curriculum Parameters (Brazil, 1998), after the 1980s the teaching of natural sciences moved closer to the humanities and social sciences, highlighting the understanding of science as a human activity, and giving importance to the history and philosophy of science in the teaching and learning process.There was also a need to identify the students' prior knowledge. From this perspective, the history of science is useful, as historically accumulated knowledge can help us understand the nature of science, as well as being relevant content for citizen education.In the same direction, the Common National Curriculum Base (Brazil, 2018) indicates that contextualization involving history does not refer only to mentioning the names of scientists and historical dates, but rather to 'presenting scientific knowledge as socially produced constructions, with their impasses and contradictions, influencing and being influenced by political, economic, technological, environmental and social conditions of each place, time and culture' (Brazil, 2018, p. 550).

A study carried out by Rodrigues (2019) which aimed to analyze the syllabuses of science teacher training courses at Portuguese universities over the last 15 years found that although this subject was introduced into the curricula of primary and secondary education with the Bologna process, it no longer exists in the syllabuses at some universities that train science teachers. In other words, the universities that train science teachers have not adjusted their syllabuses to the curriculum changes that have been made.We believe it is essential to create opportunities for future and current teachers to reflect on the possible uses of the history of science in different domains, such as planning, teaching, and assessment (Rodrigues, 2019).

Incorporating the History of Science into teaching helps to stimulate reflection on the scientific method, or even on the foundations of the construction of scientific knowledge. Analyzing historical cases in which theories were replaced or revised can highlight the importance of observation, experimentation, hypothesis formulation, and concept revision. This historical approach can promote a critical attitude towards established knowledge and encourages undergraduates to question and explore the world around them continually.

By integrating the history of science into undergraduate education, an awareness of the cumulative nature of scientific knowledge and the importance of continuous research is created. This not only enriches the understanding of scientific concepts but also strengthens critical analysis, creative thinking, and problem-solving skills in future science professionals. In short, the history of science plays a vital role in the teaching and training of undergraduates, providing valuable insights into the nature of scientific practice, fostering a critical mindset, and preparing students to contribute significantly to the advancement of science in the future (Duarte, 2004).

Several episodes from the history of biology and infectious diseases are very rich examples to be used in the classroom to discuss aspects of scientific research and the elements that make it up, such as the history of puerperal fever studied by the Hungarian doctor Ignás Semmvelweis in 1846. Part of this history was used in the 2012 Program International Student Assessment (PISA) Science test, seeking students' understanding of the issues involved in prioritizing evidence.

In this study, we used more detailed aspects of the text that presents the doctor's work on puerperal fever in order to identify and analyze investigative elements present in the conceptions of undergraduates from two different universities, based on their reading of the material.

Based on the above, we are interested in investigating the participants' understanding about the elements involved in scientific research. In this way, we sought to answer the following question in this study: what elements of scientific research do undergraduates identify in a text on the history of science?

This study is part of a larger research project carried out in partnership with professors from a university in Brazil and another in Portugal. In this specific case, the students were from different courses, as the interest in this study is the undergraduates' understanding of investigative elements, regardless of the courses they take.

2. Investigative Elements and Scientific Knowledge

Scientific skepticism is a growing phenomenon in society and has worried the scientific community as well as teachers in schools. This phenomenon is characterized by a lack of trust in the knowledge claims generated by scientists (Osborne & Pimentel, 2022). This situation stems from a lack of knowledge about how scientists generate reliable claims in their studies (Noora et al, 2024). Therefore, some considerations about the nature of research in science are necessary.

Scientific research can be understood as an intentional process to diagnose situations, formulate questions, plan, research conjectures, search for information, build models, and debate with partners using evidence and representations, to propose coherent arguments (Constantinou et al., 2018). This approach has been recommended for science teaching and learning for several years.

A study carried out by Pedaste et al. (2015) based on a systematic review of the literature on investigative cycles and the elements that make up research, points out that the central elements in an investigation are the question that initiates the investigative process, the formulation of hypotheses that are tested, for example, by experiments, obtaining and interpreting the data, discussion, conclusion to draw inferences, and communication of the results.

Studies by Cardoso & Scarpa (2018) describe the elements that can be distinguished in a scientific investigation. In summary, the authors consider these elements to be the problem/question; hypothesis/prediction; planning; data collection; conclusion, and future stages of the investigation.

The literature review carried out by Pauletti & Morais (2021), on the last ten years of publications on inquiry teaching, points to the importance of undergraduates who are going to teach classes in Natural Sciences having contact with investigative practices during their initial training, as this helps with their conceptual understanding of science, as well as contact with the elements of a scientific investigation.

3. Methodological Procedures

This research was carried out from a qualitative perspective, which deals with the meanings, understandings and written production of the students. It is descriptive research, as it aims to describe the facts and phenomena involved (Triviños, 1987), specifically in this study, developed from the record of the reflections made by academics after reading the history of puerperal fever.

The research participants were undergraduates, fifteen from the fourth year of the Biological Sciences course at a Brazilian university in the state of Paraná and fifteen from the first and second years at a Portuguese university who were attending the master’s course in Teacher Training for Basic Education. The lecturers from both universities have a partnership for developing a research project studying inquiry teaching in teacher training. The undergraduates from both universities took part in a training course entitled 'Teaching by Research and Applications in the Classroom,' taught by the research professors from both universities. All the course activities were carried out in groups of four or five participants. In Portugal, the course took place in March 2023 and in Brazil in April 2023.

In the first stage of the course, the students carried out activities intending to identify their understanding of the elements that make up a scientific investigation to continue with the other stages of the course.

We emphasize that in order to carry out the course on Teaching by Inquiry, it was essential to identify the students' understanding of the elements of a scientific investigation. Therefore, in this study we present the results obtained by the students from the two countries, concerning the reading activity of the aforementioned text.

The text entitled “The History of Puerperal Fever” presents a brief history of the studies by the Hungarian doctor Ignác Fülöp Semmelweis in the 19th century and was used during an activity at the beginning of the course.

The history of puerperal fever: an example of scientific procedure was the discovery, at the beginning of the 19th century, of the importance of hygiene in medicine. At that time, in the Vienna General Hospital, around 25% to 30% of women who had babies were affected by a serious illness known as puerperal fever. The Hungarian doctor Ignác Fülöp Semmelweis (1818 - 1865) noticed that the incidence of the disease was higher when childbirth was attended by professors and medical students than when it was attended by nurses. What could be the explanation for this difference?

Being a fan of the scientific procedure, Semmelweis began to gather all the facts related to puerperal fever in order to find an explanation. Two main facts caught his attention:

Fact 1: Puerperal fever occurred mainly in the hospital environment; women who gave birth at home rarely had the disease.

Fact 2: In the nurses' ward, most of the women assisted lay on their sides during childbirth, while in the doctors' and students' ward, the parturient always lay on her back.

Based on these facts, Semmelweis came up with the following hypothesis: giving birth, lying on your back in a hospital, and increases the risk of having puerperal fever. To test the validity of his hypothesis, Semmelweis made the following prediction: If deliveries in the doctors' ward were to take place with parturients lying on their sides, the incidence of puerperal fever would decrease, becoming similar to that in the nurses' ward.He convinced some doctors to adopt the procedure used by nurses, i.e., to lay parturients on their sides, so that he could test his hypothesis. However, this did nothing to reduce the incidence of the disease. Thus, the prediction was not confirmed, and the hypothesis was rejected. As he continued to investigate the subject, he became aware of a new fact, which suggested a new explanation for puerperal fever:

Fact 3: A physician cut himself with a scalpel while dissecting a corpse and died of the same symptoms of puerperal fever.

Linking this new fact to the previous ones, Semmelweis had a hunch that the sickness of the parturients could be caused by something present in the corpses that was somehow transmitted to them. Following this new lead, the physician remembered another fact:

Fact 4: Physicians and medicine students took care of parturients immediately after dissecting cadavers in anatomy classes; they didn't wash their hands or surgical instruments between the two activities.

Based on these new facts, Semmelweis formulated a new hypothesis: puerperal fever is caused by some matter present in cadavers, transmitted to parturients by physicians and students, through contaminated hands and surgical instruments. If this new hypothesis were true, the following prediction could be made: if physicians and students washed their hands and surgical instruments thoroughly before attending parturients, the incidence of puerperal fever would decrease.

At great expense, Semmelweis persuaded some physicians and students to wash their hands with a chlorine solution before attending to parturients. The result was that, among the patients cared for by those who adopted this practice, the disease disappeared. Given this result, he accepted the new hypothesis as the explanation for the origin of the disease.

Semmelweis' procedures did not convince most of his medical colleagues, who could not understand and accept the evidence. It was only years later that the principles of hygiene were adopted in most hospitals in Europe. Today we know that puerperal fever is caused by microorganisms that proliferate in corpses and not by cadaveric matter, as Semmelweis had thought. This shows one of the great advantages of the scientific procedure, even without knowing the complete 'truth' about the facts; it is possible to adopt an appropriate method, based on predictions from hypotheses (Amabis & Martho, 2004, p. 12)

This narrative was also described by Broechat & Gomes (2020) to highlight the importance of handwashing throughout history in the paper entitled Ignaz Semmelweis: The lessons that the history of handwashing teaches us.

We believe that using a narrative text about a historical episode is an excellent teaching resource for identifying investigative elements. In this way, the students were instructed to individually read the printed text entitled "Puerperal Fever" and answer the question: what elements in the text are part of a scientific investigation? The students were divided into groups of 4. They discussed the question and took notes on a separate sheet of paper, which was then handed over to the research professors, who were teaching the course, for later analysis of the written production.

The research was approved by the University's Research Ethics Committee (CEP), under protocol number 5.463.099, and CAAE 58709222.6.0000.5231. All participants signed an informed consent form (TCLE).

4. Data presentation and analysis

The answers given by the five groups who took part in the course in Brazil and the four groups who took part in the course in Portugal to the question posed to them are shown in Table I. The students' answers are arranged as each group wrote them.

Table 1

Student responses to the proposed activity Brazilian University

Table I: Student responses to the proposed activity

	Group 1	Group 2	Group 3	Group4	Group 5
Brazilian University	Problem: Women dying when giving birth in hospital Hypothesis: 1- concerning the position of women in childbirth, after experimentation, applying the same position as when they gave birth at home, in hospital births. The contamination of instruments and the hands of professors and students after handling cadavers in anatomy classes and subsequent contact with pregnant women.	• Problem: The incidence of the disease was higher when births were attended by professors and medical students than when they were attended by nurses. • Hypothesis: giving birth lying on your back in hospital increases the risk of puerperal fever. Puerperal fever is caused by some material present in corpses, transmitted by doctors and students, through contaminated hands and surgical instruments. • Evidence: the facts cited and the tests carried out. • Conclusion: The fever was caused by cadaveric matter.	• Problem: differences between students and nurses. • Observation of data and facts. • Raising hypotheses. • Experimentation: testing positions. • Comparing evidence with refuted hypotheses. • Reformulating hypotheses. • Experimentation and confirmation of hypotheses. Conclusion	• Problem: noticed a case. • Fact 1 and fact 2 and raised hypotheses. • Tested fact 2 (women lying on their sides and backs) and concluded that it did not resolve the incidence of the disease, rejecting the hypothesis. • Observed empirically and raised new hypotheses. • Tested a new hypothesis, in which the disease disappeared. Didn'tactually conclude the cause (microorganisms) but understood the importance of hygiene.	The elements present in the text that are part of an investigation are: presentation of the facts, elaboration of hypotheses based on facts, testing of hypotheses (rejected), accumulation of new evidence creating new hypotheses (confirmed), based on the confirmed hypotheses a solution to the problem presented
	Group 1	**Group 2**	**Group 3**	**Group 4**	
Portuguese University	• Formulated the problem question • Observed the facts (evidence) • Raising hypotheses • Investigated through exploration and experimentation (scientific procedure) • Interpreted data • Prediction • Conclusion (accepted the hypothesis as an explanation) Evolution of the scientific elements of the conclusion.	• Problem question • Hypothesis formulation • Experimentation/testing the validity of hypotheses • Data collection • Conclusion/reflection • Predicting results • Data analysis • Contextualization	• Problem question • Evidence • Formulating and explaining evidence • Linking explanations to scientific knowledge • Data interpretation • New evidence • Linking explanations to new evidence • Results/conclusions Scientific evolution.	• Guidelines • Question to be investigated • Formulating a hypothesis • Experimentation and exploration • Data interpretation • Formulating new hypotheses • Experimentation and exploration • Data interpretation • Drawing a conclusion Research leads to future research	

Source: The authors

The students' answers and the terms they used were grouped according to the investigative elements indicated by Pedaste et al. (2015) and Cardoso & Scarpa (2018) into: problem question; observation of facts; hypothesis; experimentation; data collection; data interpretation; hypothesis testing; evidence; reformulation of hypotheses; experimentation; data analysis; articulation between data, evidence and scientific knowledge; prediction; results/conclusions; and future research. The data has been reorganized in Table 2.

Table 2

Organization of the investigative elements in the analysis of the history of puerperal fever

Investigative elements	Brazilian University					Portuguese University			
	Group 1	Group2	Group 3	Group 4	Group 5	Group 1	Group 2	Group 3	Group 4
Problem question	Problem	Problem	Problem, difference between students and nurses	Problem, noticed a case	Presentation of the fact.	Formulated the problem question.	Problem question.	Problem question.	Question to be investigated.
Observation of the facts	Women dying when giving birth in hospital	The incidence of the disease was higher when births were attended by professors and medical students than when they were attended by nurses.	Observation of data and facts.	Fact 1 and fact 2	From facts	Observed the facts (evidence)		Evidence.	
Hypothesis	Regarding the position of women in childbirth, after experimentation, applying	Hypothesis:	Raising hypotheses	Raised hypotheses.	Drawing up hypotheses.	Raising hypotheses.	Formulating hypotheses.	Formulating hypotheses.	Formulating hypotheses.

	the same position as when they gave birth at home, in hospital births.								
Experimentation	The contamination of instruments and the hands of professors and students after handling cadavers in anatomy classes.		- Experimentation: testing positions. - Experimentation and confirmation of hypotheses.	(women lying on their sides and backs) Tested a new hypothesis, in which the disease disappeared.	hypothesis test (rejected)	Investigated through exploration and experimentation (scientific procedure)	Experimenting/testing the validity of hypotheses	Linking explanations to scientific knowledge	- Experimentation and exploration. - Experimentation and exploration.
Data collection							Data collection		
Data interpretation		Puerperal fever is caused by some matter present in cadavers, transmitted by physicians and students through contaminated hands and surgical instru-		Tested fact 2 (women lying on their sides and backs) and concluded that it did not resolve the incidence of the disease, rejecting the hypoth-		Interpreted data.	Reflection	Data interpretation.	- Data interpretation. - Data interpretation.

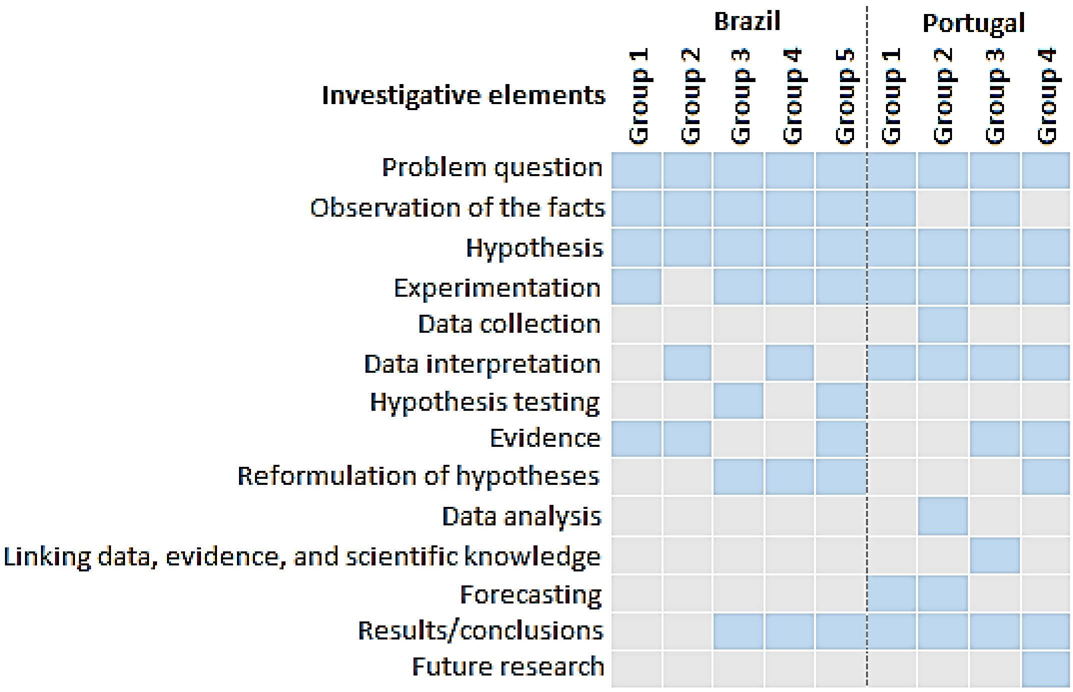
		ments.		esis.						
Hypothesis testing			Confronting the evidence with the refuted hypotheses.		Hypothesis testing					
Evidence		Evidence: the facts cited, and the tests carried out.			Accumulated new evidence			New evidence	Experimentation and exploration.	
Reformulation of hypotheses.			Reformulating the hypotheses.	Observed empirically and raised new hypotheses.	Creating new (confirmed) hypotheses				Formulating new hypotheses.	
Data analysis							Data analysis			
Linking data, evidence and scientific knowledge..								- Articulating explanations to scientific knowledg. - Articulating explanations of new evidence.		
Forecast						Forecast	Forecasting results.			
Results/ conclusions			Conclusion.	did not actually conclude the cause (microorganisms) but understood the im-	based on the confirmed hypotheses, generated a solution to the problem present-	Conclusion (accepted the hypothesis as an explanation).	Conclusion	Results/ conclusions.	Drawing up a conclusion.	

				portance of hy-giene.	ed.				
Future re-search.									Re-search leads to future re-search.

Source: The authors.

The investigative elements found in the students' answers were tabulated and represented in Chart 1, which shows a map of the identification of the investigative elements in each group of students from Brazil and Portugal.

Figure 1. *Chart I - Map identifying the investigative elements by group*



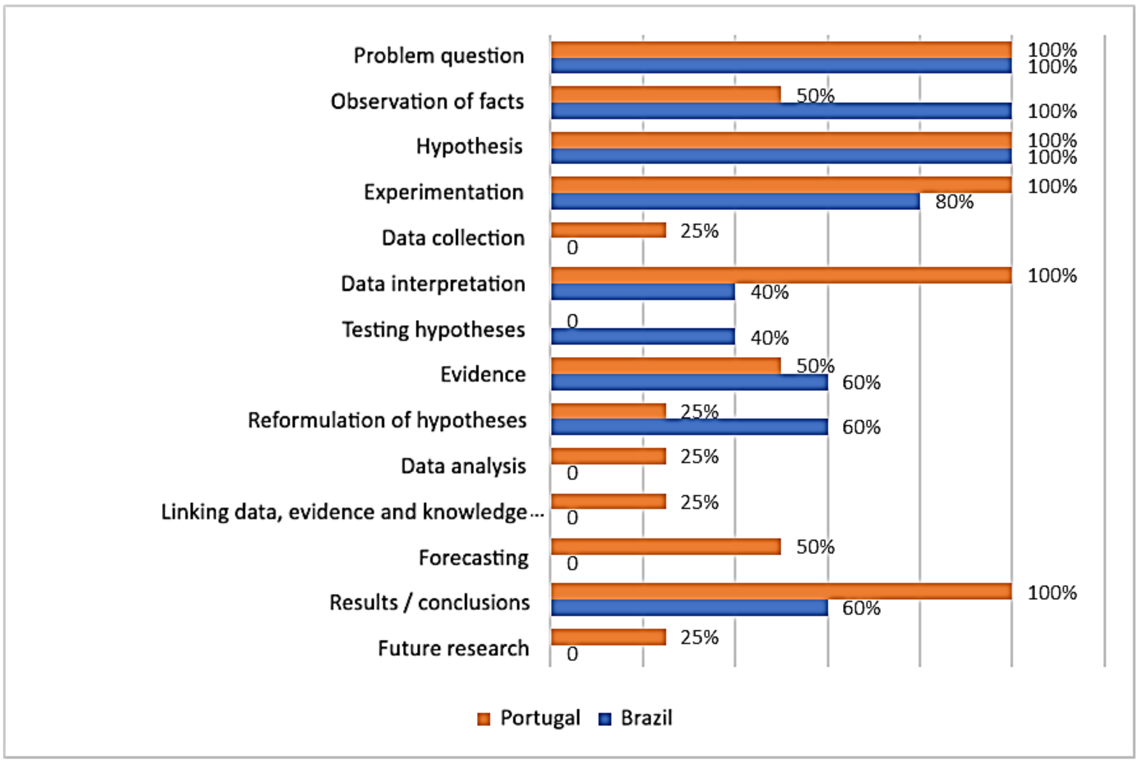
Note. The elements identified are highlighted in light blue.

Source: The authors

The investigative elements 'problem question' and 'hypotheses' were mentioned in all the groups. However, 'hypothesis testing' was only mentioned by two groups in Brazil, and ' reformulation of hypothesis' by one group in Portugal and three in Brazil. The element 'observation of the facts' was mentioned by students in all the groups in Brazil, and only two in Portugal. The investigative elements 'data interpretation,' 'experimentation,' and 'results/conclusion' were mentioned by all the groups in Portugal. 'Evidence' appeared in three groups in Brazil, and only two in Portugal. The element of 'forecasting' was only mentioned by two groups in Portugal and none in Brazil. The possibility of 'future investigations' is highlighted by Cardoso & Scarpa (2018); however, only one group from Portugal cited this investigative element.

The information in Chart 1 has been reorganized in Chart 2, which shows the percentage of groups from Brazil and Portugal who indicated the investigative elements under analysis in this paper. Each group from Brazil represents 20% of the Brazilian groups that took part in the workshop and each group from Portugal represents 25% of the Portuguese groups. Based on the information presented in Chart 2, it is possible to see which investigative elements are more frequent in the two countries, as well as which investigative elements are more prevalent in one of the countries. This information may indicate some difference in the training process of academics in the two countries, but it would only be possible to say whether there are significant differences for a larger sample of academics.

Figure 2. *Chart II – Research elements, in %, at Brazilian (BR) and Portuguese (PT) universities*



Source: The authors

In the text, with the historical episode made available to the students, there was explicit reference to the terms fact, hypothesis, hypothesis testing, hypothesis confirmation, evidence, and prediction, as can be seen in Amabis and Martho (2004). As for the investigative elements problem question; experimentation; data collection, data interpretation; articulation between data, evidence and scientific knowledge; results; conclusion; and future investigations, they are not mentioned in the text, but it was possible for the students to make inferences about the presence of these elements as the history was presented in detail.

According to Bachelard (1996), scientific knowledge develops from questioning, with problematization and doubt being essential elements for starting the investigative process. In this study, the investigative element 'problem question' was mentioned by all the groups, both at the Brazilian and Portuguese universities. However, group 3 from Brazil mentioned the term problem but recognized that it was the difference between students and nurses and not the death of women.

Regarding the observation of the facts, it was indicated by students in all the groups in Brazil and two groups at the university in Portugal (50.0%). 'Data collection' was an element only considered at the university in Portugal, in one of the participating groups (25%).

About the hypothesis, Praia et al. (2002) state that it plays a role in articulating and dialoguing between theories, observations, and experiments, serving as a guide for the research itself, but once the hypothesis has been formulated, it needs to be confirmed. In the observations made here, the term 'hypothesis' was mentioned in all the groups, both at the Brazilian and Portuguese universities. It can be seen that this is an element of scientific research that is easily identified by the students, but they lack clarity about the testing of hypotheses. In this sense, 'hypothesis testing' was only indicated in two groups from Brazil (40.0%) and was absent from the productions of the students from the Portuguese university. The investigative element of 'reformulating the hypothesis' was indicated by participants in one group in Portugal (25%) and three in Brazil (60.0%).

On the other hand, the term 'evidence' appears in three groups in Brazil (60.0%) and two in Portugal (50.0%), while 'prediction' was only mentioned by two groups in Portugal (50.0%) and no group in Brazil. Considering these aspects, it is important to note that Carvalho et al. (2018) admits, in addition to the investigative elements already mentioned, the need to prioritize evidence.

In the investigation planning phase, according to Azevedo (2018), it is decided how the data will be obtained to test the hypotheses, from the necessary material to setting up the experimental arrangement, collecting and analyzing the data to thinking about concluding the investigation with an answer to the question. In this sense, the element 'experimentation' appears in all the groups at the Portuguese university (100.0%), and in four groups at the Brazilian university (80.0%).'Data analysis,' 'articulation of data,' 'evidence and scientific knowledge' and 'future research' were only covered by the groups from the Portuguese university. 'Data interpretation' and 'results/conclusions' were mentioned by all the groups in Portugal, and by two and three groups respectively (40.0% and 60.0%) in Brazil.

We believe that the use of the history of science in the training of undergraduates to work in disciplines in the natural sciences has the potential both to help students understand the foundations of scientific knowledge and to help identify the conceptions they have about the principles of the construction of scientific knowledge.

In the historical episode made available to the students, there was explicit reference to the terms 'fact,' 'hypothesis,' 'hypothesis testing,' 'hypothesis confirmation,' 'evidence,' and 'prediction.' The elements 'observation of the facts,' 'hypothesis testing,' and 'hypothesis confirmation' were indicated by more groups from the Brazilian university (with 100.0%, 40.0%, and 60%, respectively), when compared to the Portuguese university (with 50.0%, 0.0%, and 25.0%, respectively).

The 'possibility of future investigations' is an element highlighted by Cardoso & Scarpa (2018) to be achieved in the process of inquiry teaching, however, only one of the groups from Portugal mentioned this investigative element (25.0%), while there was no identification of this element in the groups from the Brazilian university. This observation draws attention to the fact that investigative sequences need to be adapted so that this investigative element can be contemplated effectively.

Concerning 'data analysis,' 'articulation of the data' and 'scientific knowledge,' although these elements are not indicated with correlated and specific terms in Semmelweis' history of puerperal fever, the Portuguese students made such an inference.

Despite the observations made in this study, that a certain group of investigative elements was covered more by the groups of students from the Brazilian university and other investigative elements were covered more effectively by the groups of students from the Portuguese university, we did not intend to compare which investigative elements are predominant in Brazil or Portugal, since this descriptive study aimed to discuss the elements present in the students' responses and thus relate these results to possible implications for teaching and student training.

5. Discussions and implications for teaching

In general, the undergraduates in the groups investigated had no difficulty in identifying the 'problem question' and 'hypothesis.' 'Evidence' and 'experimentation' were also identified by a good proportion of the groups considered. The elements 'data collection,' 'data analysis,' and 'future research' were the least identified by the undergraduates.

The identification of the elements of scientific investigation by different groups of undergraduates from the two countries provides a framework for science teachers and researchers to develop approaches to teaching the Nature of Science, especially those that deal with the history of science to give greater emphasis and approach to the elements that the students had difficulty identifying.

Gizaw and Sota (2023) reviewed the literature on strategies available to improve students' scientific investigation skills. The authors argue that in order to develop these skills and understand the elements of a scientific investigation, teaching must go beyond simply providing students with an understanding of the main concepts of the content, so we consider that practices such as those involving the exploration of texts related to the History of Science can favor this understanding. In this sense, Noora et al (2024) state that one way to promote a better understanding of investigative processes in science is to use activities that include epistemic practices. These practices are procedures that scientists use to generate reliable knowledge claims and include investigative elements.

Contact with scientific practices, as well as understanding the procedures and characteristics of scientific research are proposed in official teaching documents in Brazil, such as the Common National Curriculum Base (Brazil, 2018), guiding documents for Basic Education; in the Common National Base - initial teacher training for Basic Education-BNC (Brazil, 2019), and in Portugal the guiding documents are the profile of the student leaving compulsory education (Martins et al., 2017), and the Essential Learning (Portugal, 2018), regarding teacher training there is the General Profile of Professional Performance of Early Childhood Educators, and Primary and Secondary School Teachers (Decreto-Lei n. 241, 2001), and, more recently, the new legal regime (Decreto-Lei n. 112, 2023) for professional qualifications for teaching in pre-school education, and primary and secondary education, approved by Decree-Law no. 112/2023 of November 29.

According to the profile of students leaving compulsory education, two of their required competencies relate to reasoning and critical thinking.

The competencies associated with reasoning and problem-solving imply that students can interpret information, plan and conduct research; manage projects and make decisions to solve problems; and develop processes leading to the construction of products and knowledge, using diverse resources.

As for critical thinking, 'students need to observe, analyze, and discuss ideas, processes or products, focusing on evidence, formulating arguments to support their positions and evaluating the impact of the decisions taken.' (Martins et al., 2017)

In terms of 'basic education,' guiding documents such as the National Research Council (2012) and the European Commission (2015) also point to the need for basic education students to learn the fundamentals of building scientific knowledge through contact with scientific practices.

In this sense, we believe that if future teachers do not have a good understanding of the fundamental elements that make up a scientific investigation, they will not be able to contribute adequately to the education of their students.

In short, the History of Science has been widely recognized in recent years as an important tool in the teaching and learning process. The History of Science offers a unique perspective on the scientific process, showing that science is not a collection of watertight facts but a dynamic process of investigation, experimentation, and revision. In addition, the History of Science provides an opportunity for teachers to address the nature of science and its methods. By discussing scientists' mistakes and advances over time, students develop a more critical and reflective view of scientific knowledge (Carvalho & Rodrigues, 2023).

Despite all these potentialities of the History of Science, there are still some difficulties in its use in the classroom context, among others: difficulty in accessing appropriate historical materials; scarcity of History of Science texts that address the specific needs of Science Teaching in the classroom (Scoaris et al., 2009; Rodrigues & Carvalho, 2016), as well as activities that address the History of Science with an emphasis on the construction of scientific knowledge like the one we used in this study.

6. Concluding remarks

This research made it possible to observe some of the main elements of scientific research that were identified by the groups of undergraduates from Brazil and Portugal.

Although some of these elements were covered more by groups from one country than those from the other, these differences were not statistically significant overall.

The results of this study also allow us to raise new questions for future research which will seek to understand the reasons for the difficulties experienced by undergraduates in identifying and relating to science teaching approaches, especially those concerning the Nature of Science and approaches involving the History and Philosophy of Science, for example: What could be the reasons for the undergraduates' failure to perceive these elements? How does this relate to the science teaching approaches practiced? How have these elements been worked on in teaching practices and addressed by research into the History and Philosophy of Science?

Therefore, better-prepared teachers will be able to develop learning at a higher conceptual level by integrating the nature of science into teaching, making a significant contribution to students' scientific education.

Ethical Considerations

All participants provided informed consent, and anonymity was ensured. Ethical approval was obtained from institutional committees in both Brazil and Portugal. The study followed international standards for research involving human subjects.

Methodology

A qualitative descriptive–interpretative methodology was adopted. Participants included Brazilian Biological Sciences undergraduates and Portuguese Teacher Training master's students. Data were collected through reading activities, guided discussions, and written reflections, followed by thematic content analysis to identify investigative elements.

Acknowledgements

The authors thank the participating universities, instructors, and students for their collaboration. Institutional support from Universidade Estadual de Londrina and Universidade Trás-os-Montes e Alto Douro is gratefully acknowledged.

Funding

This research received no specific funding from public, commercial, or non-profit agencies.

Conflict of Interest. The authors declare no conflict of interest.

References

1. Deboer, G. E. (2006). Historical perspectives on inquiry teaching in schools. [Perspectivas históricas sobre la enseñanza de la investigación en las escuelas]. In L. B. Flick, & N. G. Lederman (Eds.), *scientific inquiry and nature of science: Implications for teaching, learning, and teacher education* (pp. 17-35). Springer Netherlands. https://george-deboer.org/wp-content/uploads/2020/10/Historical-Perspectives-on-Inquiry-Teaching-in-Schools.pdf
2. Villarreal, J. E. Muñoz García, G., Pérez Olivera, H., Corredor Gómez, A., Martines Morales, E. A., Porto Solano, A. (2017). El desarrollo de habilidades investigativas a partir de resolución de problemas. Las matemáticas y el estado nutricional de los estudiantes. *Revista Lasallista de Investigación, 14*(1), 162-169. https://www.redalyc.org/pdf/695/69551301015.pdf
3. Salazar, A. O. Rojas, L. L.. Castro., & Macassi, A. L. S. (2019). Desarrollo de habilidades investigativas en estudiantes de enfermería: nuevos retos en el contexto formativo. *Investigación Valdizana, 13*(2), 107-112. https://doi.org/10.33554/riv.13.2.236
4. Barboza, D. A. P. (2021). *Desenvolvimento de habilidades cognitivas por meio de uma sequência de aulas experimentais investigativas de química orgânica no ensino médio* [Dissertação Mestrado, Universidade Federal do Rio Grande do Sul]. Repositório institucional. http://hdl.handle.net/10183/224890
5. National Research Council. (2000). *Inquiry and the national science education standards.* National Academy Press. https://nap.nationalacademies.org/catalog/9596/inquiry-and-the-national-science-education-standards-a-guide-for
6. National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* National Academy Press. https://nap.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts
7. Cutrera, G. E. (2003). La actividad científica y la génesis del conocimiento científico en los textos escolares de ciencias naturales. Un análisis de clasificación. *Revista Iberoamericana de Educación*, 1-13. https://rieoei.org/historico/deloslectores/672Cutrera.PDF
8. Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education, 36*(15), 2534-2553.
9. Scarpa, D. L., & Campos, N. F. (2018). Potencialidades do ensino de Biologia por Investigação. *Estudos avançados,* 32(94), 25-41. https://www.scielo.br/j/ea/a/RKrKKvjmY7MX7Q5DChtvN5N/?format=pdf&lang=pt
10. Matthews, M. S. (1995). História, filosofia e ensino de ciências: a tendência atual de reaproximação. *Caderno Brasileiro de Ensino de Física, 12*(3), 164-214. https://dialnet.unirioja.es/descarga/articulo/5165906.pdf
11. Vannucchi, A. I. (1996). *História e Filosofia da Ciência: da teoria para a sala de aula* [Doctoral Dissertation, Universidade de São Paulo]. Repositório. https://doi.org/10.11606/D.81.1997.tde-15062005-164939
12. Martins, L. A., & Brito, A. A. (2006). História da ciência e o ensino da genética e evolução no nível médio: um estudo de caso. In C. C. Silva (Ed.), *Estudos de história e filosofia das ciências: subsídios para a aplicação no ensino* (pp. 246-280). Livraria da Física.
13. Ortiz, E., & Silva, M. R. (2016). O uso de abordagens da História da Ciência no ensino de Biologia: uma proposta para trabalhar a participação da cientista Rosalind Franklin na construção do modelo da dupla hélice do DNA. *Investigações em Ensino de Ciências, 21*(1), 106-123. https://doi.org/10.22600/1518-8795.ienci2016v21n1p106

14. Cachapuz, A., Praia, J., Paixão, F., & Martins, I. (2000). Uma visão sobre o ensino das ciências no pós-mudança conceptual: contributos para a formação de professores. *Inovação*, *13*(2-3), 117-137. http://hdl.handle.net/10400.11/1363
15. Rodrigues, I. T. (2019). A História da Ciência na formação inicial de professores de ciências. *História da Ciência e Ensino: Construindo Interfaces*, *20*, 2-14. https://doi.org/10.23925/2178-2911.2019v20p2-14
16. Duarte, M. C. (2003). *A história da ciência e o ensino das ciências: contributos e desafios. Lição de Síntese das Provas de Agregação* [não publicada]. Universidade do Minho.
17. Duarte, M. C. (2004). A história da ciência na prática de professores portugueses: implicações para a formação de professores de ciências. *Ciência & Educação*, *10*(3), 317-331. https://doi.org/10.1590/S1516-73132004000300002
18. Brasil. Ministério da Educação. (1998). *Parâmetros Curriculares Nacionais. Ciências Naturais*. MEC. http://portal.mec.gov.br/seb/arquivos/pdf/ciencias.pdf
19. Brasil. Ministério da Educação. (2018). *Base Nacional Comum Curricular*. MEC. http://basenacionalcomum.mec.gov.br/images/BNCC_EI_EF_110518_versaofinal_site.pdf
20. Osborne, J., & Pimentel, D. (2022). Ciência, desinformação e o papel da educação. *Ciência, 378*(6617), 246-248.
21. Noora F. N. (2024). Noushad, N. F., Yoon, S. A., Chinn, C. A., Yang, Z., Hussain-Abidi, H., & Hunkar, K. (2024). Scientists don't know the truth; they tell you what they know to be true!: Shaping High School Students Understanding of How Scientists Establish Trustworthy Claims Using Epistemic Practices. In Lindgren, R., Asino, T. I., Kyza, E. A., Looi, C. K., Keifert, D. T., & Suárez, E. (Eds.), *International Conference of the Learning Sciences* [Proceedings]. 18th International Society of the Learning Sciences. https://doi.org/10.22318/icls2024.513395
22. Constantinou, C. P., Tsivitanidou, O. E., & Rybska, E. (2018). What is inquiry-based science teaching and learning?. In O. E. Tsivitanidou, P. Gray, E. Rybska, L. Louca, & C. P. Constantinou (Eds.). *Professional development for inquiry-based science teaching and learning* (pp. 1-23). Springer.
23. Pedaste, M., Mäeots M., Siiman, L. A., Jong, T., van Riesen, S. A.N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003
24. Cardoso, M. J. C., & Scarpa, D. L. (2018). Diagnóstico de Elementos do Ensino de Ciências por Investigação (DEEnCI): uma ferramenta de análise de propostas de ensino investigativas. *Revista Brasileira de Pesquisa em Educação em Ciência*, *18*(3), 1025-1059. https://doi.org/10.28976/1984-2686rbpec20181831025
25. Pauletti, F., & Morais, C. (2021). Inquiry-basedscienceeducation: revisão de uma década de produções científicas. *Revista Brasileira de Ensino de Ciências e Matemática*, *5*(1), 350-372. https://pdfs.semanticscholar.org/7859/4ce5b03624a445040a283479bff1e26ee0c6.pdf
26. Trivinos, A. N. S. (1987). *Introdução à pesquisa em ciências sociais*: *a pesquisa qualitativa em educação*. Atlas.
27. Amabis, J. M., & Martho, G. R. (2004). *Biologia Moderna* (Vol. 1). Moderna.
28. Broechat, J., & Gomes, H. I. S. (2020). *Ignaz Semmelweis: as lições que a história da lavagem das mãos ensina*. https://coc.fiocruz.br/todas-as-noticias/ignaz-semmelweis-as-licoes-que-a-historia-da-lavagem-das-maos-ensina/
29. Pedaste, M., Mäeots, M., Siiman, L. A., Jong, T., van Riesen, S. A.N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educationalresearch Review*, *14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003
30. Bachelard, G. (1996). *A formação do espírito científico*. Contraponto.
31. Praia, J., Cachapuz, A., & Gil-Pérez, D. (2002). A hipótese e a experiência científica em educação em ciência: contributos para uma reorientação epistemológica. *Ciência & Educação, 8*(2), 253-262. https://doi.org/10.1590/S1516-73132002000200009
32. Carvalho, H. N., Leite, J. L., Lima, R. C. P., Oliveira, J. C. C., & Delgado, O. T. (2018). Experimentação no ensino de ciências: utilizando a química como proposta para experimentação no mestrado de ensino de ciências. *Revista Ambiente: Gestão e Desenvolvimento*, *11*(1), 52-64. https://doi.org/10.24979/130
33. Azevedo, M. C. P. S. (2018). Ensino por investigação: problematizando as atividades em sala de aula. In Carvalho, A. M. P. (Org.). *Ensino de Ciências Unindo a Pesquisa e a Prática* (2a ed. pp. 19-33). Cengage Learning.
34. Gizaw, G., & Sota, S. (2023). Improving science process skills of students: A review of literature. *Science*

Education International, *34*(3), 216-224. https://www.icaseonline.net/journal/index.php/sei/article/view/526

35. Brasil. Ministério da Educação. (2019). *Base Nacional Comum para a Formação de Professores*. MEC.
36. Martins, G. d'Oliveira, Gomes, C. A. S., Brocardo, J. M. L., Pedroso, J. V., Carrilo, J. L. A., Silva, L M. U., Encarnação, M. M. G. A., Horta, M. J. A. C., Calçada, M. T. C. S., Nery, R. F. V., & Rodrigues, S. M. C. V. (2017). *Perfil dos alunos à saída da escolaridade obrigatória*. República Portuguesa. https://comum.rcaap.pt/bitstream/10400.26/22377/1/perfil_dos_alunos.pdf
37. Portugal. Direção-Geral da Educação. (2018). *Aprendizagens Essenciais Ensino Básico*. https://www.dge.mec.pt/aprendizagens-essenciais-ensino-basico
38. Decreto-Lei n. 241/2001 de 30 de agosto. (2001). -Perfil específico de desempenho profissional do educador de infância e professor de 1. ciclo. *Diário da República*, n. º 201/2001–I Série. https://www.dge.mec.pt/sites/default/files/Basico/dl241_01.pdf
39. Decreto-Lei n. 112/2023 de 29 de novembro. (2023). Altera o regime jurídico da habilitação profissional para a docência na educação pré-escolar e nos ensinos básico e secundário. *Diário da República*, n. º 231/2023–I Série. https://files.diariodarepublica.pt/1s/2023/11/23100/0000400014.pdf
40. Euroepan Comission. (2015). *Key competences for lifelong learning: a European reference framework.* Commission of the European Communities. http://www.britishcouncil.org/sites/britishcouncil.uk2/files/youth-in-action-keycomp-en.pdf
41. Scoaris, R. C. O., Benevides-Pereira, A. M. T., &, Santin, O., Filho. (2009). Elaboração e validação de um instrumento de avaliação de atitudes frente ao uso de história da ciência no ensino de ciências. *REEC: Revista electrónica de enseñanza de las ciencias*, 8(3),901-922. https://reec.uvigo.es/volumenes/volumen08/ART8_Vol8_N3.pdf