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Inquiry-Based Teaching in the Chemistry Curriculum Component in Upper Secondary Education

Danylo David de Lima Silva
danylodavidlima@gmail.com
0000-0003-2288-046X
Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brasil.

Verônica Tavares Santos Batinga
veratsb@gmail.com
0000-0002-9660-396X
Universidade Federal Rural de Pernambuco, Recife, Pernambuco, Brasil

ABSTRACT

This study presents a literature review whose objective is to identify theoretical and methodological aspects present in research that addresses inquiry-based teaching, especially in the discipline of chemistry, within the context of upper secondary education. To this end, articles on this topic published in national and international journals in the field of science education between 2016 and 2020 were analyzed. The study adopts a qualitative approach with regard to data analysis. A total of 25 articles related to this topic were identified, focusing on the teaching of chemistry contents, with a predominance of studies in the field of physical chemistry. The results indicate the journals, titles, objectives, and participants of the studies, the year of publication, and the teaching strategies/resources used, revealing elements and characteristics of research that addresses inquiry-based teaching. The purposes and stages inherent to the investigated theme were addressed in most of the studies. Various teaching strategies were adopted to promote investigative activities, particularly the use of problem-solving and experimentation. This study is expected to contribute to the systematization and dissemination of research on inquiry-based teaching in the field of chemistry education at the upper secondary level.

KEYWORDS: Chemistry Teaching. Experimentation. Problems. Didactic Sequence.

INTRODUCTION

Inquiry-Based Teaching (IBT) is a pedagogical approach that starts from questions or problems and enables students to express different points of view; formulate and/or test hypotheses; construct explanations about phenomena through observation, data collection, recording and analysis, communication, and systematization of knowledge in the problem-solving process, aiming at the construction of meaning (Sasseron, 2015).

Di Mauro, Furman, and Bravo (2015) argue that working with scientific inquiry skills—considering their adaptations to the school context—such as data analysis, research planning to solve problems, and the interpretation of results from investigative activities and experiments, also constitutes one of the teaching and learning objectives proposed in science curricula in many countries.

Despite advances in research across various fields of knowledge, the teaching and learning process in schools often still privileges the transmission and reception of knowledge. Considering this reality, Longino (2002) and Sedano and Carvalho (2017) point out the possibility of creating learning scenarios within a social context closer to students' realities, prioritizing social interaction between students and the teacher. Such aspects may influence the effectiveness of learning.

Longino (2002) and Sedano and Carvalho (2017) state that inquiry-oriented science teaching also promotes the exchange of ideas through social interactions occurring among student–student, student–teacher, and student–expert, in addition to contributing to the development of autonomy in the classroom (Sedano; Carvalho, 2017). In this sense, it is necessary for teachers to seek more dynamic teaching practices that encompass these interactions and arouse students' interest in studying and learning science.

The term inquiry began to be discussed more systematically with Project Synthesis by the National Science Foundation (NSF), as its meaning was ambiguous and appeared confusing. One understanding of this term referred to inquiry as content, for example, learning about algebra, classical physics, or organic chemistry. Another understanding involved integrating inquiry into content strategically, as a means of constructing meaning and promoting more effective science learning (Barrow, 2006).

In this direction, this study sought to answer the following research question: What theoretical and methodological characteristics and elements are present in research on inquiry-based teaching in the discipline of chemistry at the upper secondary education level? To this end, the following objective was established: to identify theoretical and methodological aspects present in research that addresses inquiry-based teaching, particularly in the discipline of chemistry within the context of upper secondary education.

WHAT DOES INQUIRY-BASED TEACHING PROPOSE?

In Brazil, the National Curriculum Parameters (Parâmetros Curriculares Nacionais – PCN) emphasize the development of students' competencies and skills, aiming to address characteristics inherent to scientific knowledge through the investigation of themes proposed for basic education (Brasil, 1999; Zômpero; Laburú, 2011). For example, the document known as PCN+ includes the proposal

to “encourage cultural enrichment activities; develop investigative practices; and design and implement projects to develop curricular content” (Brasil, 2002, p. 4).

Currently, inquiry-based teaching is understood as a pedagogical approach. According to Sasseron and Carvalho (2008), the promotion of this approach in the science classroom may occur through scientific practice itself, for instance, by introducing discussions during the construction of concepts and throughout the process of sharing ideas among students. This approach starts from problems or questions as activities that guide the development of theoretical, practical, and experimental tasks, which are linked to information-seeking processes and prioritize student autonomy throughout the entire investigative process (Carvalho, 2013).

According to Pérez (1993), the purposes of inquiry-based teaching include: (1) providing students with the opportunity to recognize a problem and use strategies to propose solutions; (2) developing the ability to plan and carry out experiments that allow hypotheses to be tested; (3) making use of observations; (4) collaborating in groups during the planning and execution of activities; (5) participating in an orderly and active manner in debates, formulating arguments and respecting others’ ideas; (6) conducting laboratory work with order, cleanliness, and safety; (7) adopting a critical attitude; and (8) producing written documents about the results obtained, using appropriate language correctly and approximating scientific discourse.

Carvalho (2011) identifies four stages for inquiry-based proposals: the problem as a means for knowledge construction; the transition from manipulative action to intellectual action in problem-solving; awareness-building; and the construction of explanations.

According to Osborne and Wittrock (1983), the introduction of scientific inquiry in the school context can be developed by engaging students in empirical and theoretical investigative activities aimed at solving problems, formulating and testing hypotheses, seeking information, analyzing evidence, communicating results, collecting data, and constructing explanations based on scientific knowledge.

The role of the teacher in inquiry-based teaching is to encourage students to think, reflect, debate, and justify their ideas, as well as to apply the knowledge constructed to new situations (Azevedo, 2004). During the planning process, teachers can create a scenario for presenting the problem, aiming to stimulate students’ interest in learning the concept addressed. Subsequently, teachers may use strategies that seek to engage students in the stages of inquiry-based teaching. Considering certain criteria is important for promoting activities and strategies, such as students’ experiences, age, language, culture, prior knowledge, and backgrounds (Nascimento; Amaral, 2012).

When students are engaged in investigative activities, they participate in describing objects and phenomena, seek and analyze evidence, and use logical reasoning and imagination to develop explanations about the natural and social world (Newman *et al.*, 2004). Consequently, inquiry-based teaching enables greater student autonomy and responsibility in the teaching and learning process, such that scientific knowledge is internalized throughout the investigative pathway, which is composed of multiple teaching strategies and resources.

METHODOLOGY

This study adopts a qualitative approach with regard to data analysis and involves processes of description and interpretation (Lüdke; André, 2013). In terms of typology, the study is characterized as bibliographic research (Gil, 2002), aiming to identify theoretical and methodological aspects present in research that addresses inquiry-based teaching, particularly in the discipline of chemistry within the context of upper secondary education.

With respect to data selection and collection criteria, the sources of data for this research consisted of articles published in national and international journals in the field of Science/Chemistry Education. The Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) Qualis strata A and B were used as criteria for journal selection, as they represent one of the main indicators of the quality of scientific publications in Brazil. Following these criteria, the journals presented in Table 01 were selected.

Table 01 – Selected journals and their Qualis strata according to CAPES.

Periódicos	Estratos
ACTA SCIENTIAE	B1
ACTIO: Docência em Ciências	B1
Alexandria: Revista de Educação em Ciências e Tecnologia	A2
Amazônia: Revista de Educação em Ciências e Matemática	A2
Chemistry Education Research and Practice	1,9*
Ciência & Ensino	A1
Educación Química	A1
Enseñanza de las Ciencias	A1
Experiência em Ensino de Ciências	B1
Investigações em Ensino de Ciências	A2
Journal of Research in Science Teaching	A1
Química Nova na Escola	B1
Research in Science & Technological Education	1,1*
Revista Brasileira de Educação	A2
Revista Brasileira de Ensino de Ciência e Tecnologia	A2
Revista Brasileira de Ensino de Ciências e Matemática	A2
Revista Brasileira de Pesquisa em Educação em Ciências	A2
Revista Debates em Ensino de Química	B4
Revista de Educação, Ciências e Matemática	A2
Revista Electrónica de Enseñanza de las Ciencias	A2

*impact factor

Source: Prepared by the authors (2021).

Initially, the search was conducted across all issues of the journals (Table 01) published between 2016 and August 2020. The titles and abstracts of each article published in the selected journals were read using the following keywords: **Inquiry-based teaching** and **Inquiry-based instructional sequences** for national journals. In addition, other terms related to inquiry-based teaching were considered:

Investigative activities, **investigative experiments**, **investigative methodology**, and **inquiry-based teaching sequence**. For international journals published in English, the following terms were used: *Inquiry-based approaches*, *Inquiry-based learning*, *Inquiry-based instructional practices*, *Investigative method*, and *Investigative activity*. For journals published in Spanish, the terms *Enseñanza de la investigación*, *Enseñanza por investigación*, *Metodología de la investigación*, *Metodología de enseñanza investigativa*, and *Inquiry-based investigación were employed*.

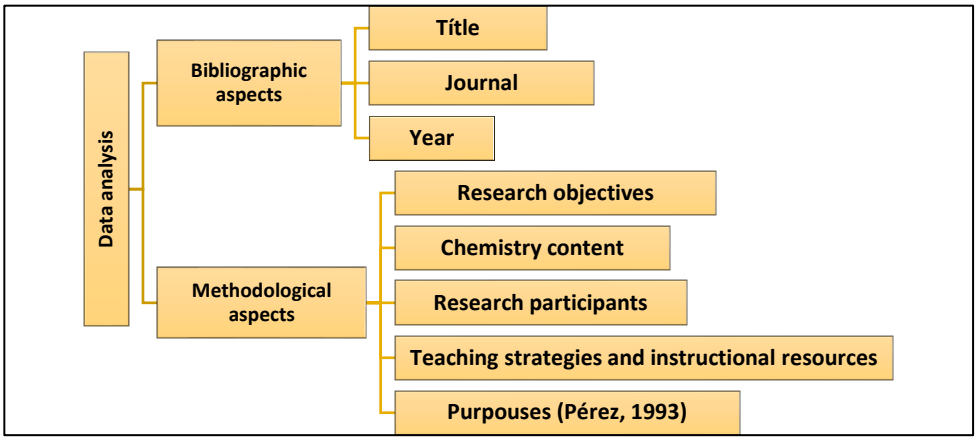
As an exclusion criterion, articles that did not present the identification of the aforementioned keywords in the title and abstract were not considered. For the inclusion criterion, articles containing the adopted keywords were considered, resulting in a total of 131 articles. Subsequently, the abstracts of these articles were read in order to identify and quantify those that addressed inquiry-based teaching with a focus on the field of chemistry at the upper secondary education level, resulting in 25 documents. These articles were identified using codes A1 to A25.

For the analysis of articles centered on inquiry-based teaching in the discipline of chemistry, two *a priori* categories were established: bibliographic aspects and methodological aspects. Regarding bibliographic aspects, the analyzed articles included the following items: (a) title of the study; (b) journal name; and (c) year of publication. These data are important because they indicate the origin of the articles, their thematic focus, and the date of publication.

With regard to methodological aspects, the articles were analyzed considering: (a) research objectives; (b) chemistry content; (c) research participants; (d) teaching strategies and instructional resources used; and (e) the purposes of inquiry-based teaching proposed by Pérez (1993). Concerning chemistry content, areas within the field of chemistry were taken into account, such as general chemistry, physical chemistry, and organic chemistry. Regarding teaching strategies, the use of problem-solving, investigative experimentation, and other activities involving video presentations and the use of software as instructional resources were considered.

The characterization of methodological aspects makes it possible to identify the target audience for which inquiry-based teaching or investigative activities are predominantly applied and how they are structured, that is, which strategies and/or resources are used for the development of this pedagogical approach. Furthermore, it allows the identification of which themes and/or chemistry contents are being studied through inquiry-based teaching. Figure 01 presents a flowchart with the analysis categories and the aspects considered.

Figure 01 – Categories adopted in data analysis.



Source: Prepared by the authors (2021).

RESULTS AND DISCUSSION

Among the 131 articles identified, those that addressed inquiry-based teaching in the discipline of chemistry (25) with research participants situated in the context of upper secondary education were selected. Table 02 presents the bibliographic aspects of the articles that address inquiry-based teaching in this field of knowledge.

Quadro 02 – Aspectos bibliográficos dos artigos analisados na disciplina de química no contexto do ensino médio

Articles	Titles	Journals	Year
A1	*Análisis del potencial del andamiaje insertado para promover la planificación de uma investigación científica em educación secundaria*.	*Educación Química*	2018
A2	Determinação de níveis de letramento científico a partir da resolução de casos investigativos envolvendo questões sociocientíficas.	*Educación Química*	2019
A3	*Desempeños del alumnado de Educación Secundaria em la evaluación de uns investigación científica em el contexto.*	*Enseñanza de las Ciencias*	2019
A4	A utilização de atividades experimentais investigativas e o uso de representações no ensino de cinética química.	Experiência em Ensino de Ciências	2019
A5	Contextualização no ensino de termoquímica por meio de uma sequência didática baseada no cenário regional "queimadas" com experimentos investigativos.	Experiência em Ensino de Ciências	2017
A6	O ensino de processo de separação de misturas a partir de situações-problemas e atividades experimentais investigativas.	Experiência em Ensino de Ciências	2018
A7	Investigação no ensino médio: sistemas de hidroponia em horta escolar para discussão de conceitos químicos.	Experiência em Ensino de Ciências	2019

A8	Aplicação de sequência didática investigativa com uso de laboratórios *online* no ensino de química em turmas do ensino médio em escola pública: uma pesquisa-ação.	Experiência em Ensino de Ciências	2020
A9	As contribuições de uma sequência didática com enfoque investigativo para o ensino de química.	Experiência em Ensino de Ciências	2020
A10	Identificação de atitudes investigativa e científica: um estudo de caso em um ambiente interativo de aprendizagem.	Investigações em Ensino de Ciências	2018
A11	A camisinha como artefato tecnológico no ensino de química.	Química Nova na Escola	2016
A12	Ensino de modelos para o átomo por meio de recursos multimídia em uma abordagem investigativa.	Química Nova na Escola	2016
A13	Limpando moedas de cobre: um laboratório químico na cozinha de casa.	Química Nova na Escola	2016
A14	Aprendizagem ativo-colaborativo-interativa: inter-relações e experimentação investigativa no ensino de eletroquímica.	Química Nova na Escola	2018
A15	Corantes: uma abordagem com enfoque ciência, tecnologia e sociedade (CTS) usando processos oxidativos avançados.	Química Nova na Escola	2018
A16	Energia, sociedade e meio ambiente no desenvolvimento de um biodigestor: a interdisciplinaridade e a tecnologia Arduino para atividades investigativas.	Química Nova na Escola	2018
A17	Uma sequência investigativa relacionada à discussão do conceito de ácido e base.	Química Nova na Escola	2018
A18	Atividade investigativa teórico-prática de química para estimular práticas científicas.	Química Nova na Escola	2019
A19	A experimentação investigativa no ensino de ciências na educação básica.	Revista Debates em Ensino de Química	2018
A20	Abordagem investigativa da química forense: uso de recursos audiovisuais e experimentação em um estudo de caso.	Revista Debates em Ensino de Química	2019
A21	Um clique para a ciência: a fotografia científica na experimentação investigativa em aulas de química.	Revista Debates em Ensino de Química	2019
A22	O desastre de Mariana como abordagem investigativa e CTSA no ensino de química.	Revista de Educação, Ciências e Matemática	2019
A23	Experimentação investigativa no ensino de química em um enfoque CTS a partir de um tema sociocientífico no ensino médio.	Revista *Electrónica de Enseñanza de las Ciencias*	2018
A24	*An inquiry-based approach of traditional 'step-by-step' experiments.*	*Chemistry Education Research and Practice*	2016
A25	High school students' engagement in planning investigations: findings from a longitudinal study in Spain.	Chemistry Education	2016

		Research and Practice	

Source: Research data (2021).

By analyzing the titles of the studies (Table 02), it is possible to observe a diversity of approaches and strategies associated with inquiry-based teaching in the field of chemistry. Among these approaches, the following can be highlighted: the use of investigative experimentation to promote inquiry-based teaching (Carvalho, 2009), as observed in articles A1, A3–A22, and A24–A25; the teaching of chemistry content through problem-based approaches as a foundation for inquiry-based teaching (Sasseron, 2015; Carvalho, 2009; Hund, 1998), as seen in articles A1–A3, A6–A7, A10, A17–A19, A21, and A25; and the discussion of concepts and teaching strategies for working with inquiry-based teaching (Sasseron, 2015), present in articles A2, A10–A12, A15–A17, and A20–A23.

Among the selected journals (Table 01), not all presented studies on inquiry-based teaching in chemistry. At the national level, the journal Química Nova na Escola stands out with eight publications; Experiência em Ensino de Ciências includes six publications addressing inquiry-based teaching; Revista Debates em Ensino de Química presents three publications; and Investigações em Ensino de Ciências and Revista de Educação, Ciências e Matemática each present one publication. At the international level, *Chemistry Education Research and Practice* and *Educación Química* each present two publications, while *Revista Electrónica de Enseñanza de las Ciencias and Enseñanza de las Ciencias* present one publication each.

The 25 articles present inquiry-based teaching and investigative activities as a pedagogical approach that can encompass multiple teaching strategies, as pointed out by Sasseron (2015), who states that investigative activities involve multifaceted tasks such as making observations, raising questions, proposing and solving problems, researching information sources, reflecting on experiences, predicting outcomes, and discussing and communicating results.

By observing the bibliographic aspects analyzed, it is possible to highlight some characteristics of research on inquiry-based teaching:

1. The titles suggest that inquiry-based teaching may encompass approaches for specific purposes, such as its articulation with scientific literacy and the use of teaching strategies to compose inquiry-based teaching
2. There are studies being developed at both national and international levels;
3. Considering the articles in the field of chemistry (Table 02) with research participants from upper secondary education, these were further analyzed with a focus on methodological aspects and are organized in Table 03.

Table 03 – Description of the articles according to methodological aspects.

Articles	Research Objectives	Chemistry Content	Participants
A1	To examine the potential of the scaffold used in an inquiry activity to guide students in research planning practices based on student performance.	Biochemistry	2nd, 3rd, and 4th years of upper secondary education
A2	To present the levels of scientific literacy of an upper secondary education class, based on reading, writing, and argumentation used to solve investigative case studies.	Biochemistry	3rd year of upper secondary education
A3	To examine upper secondary students' performance in assessing the quality of scientific investigation planning.	Biochemistry	2nd, 3rd, and 4th years of upper secondary education
A4	To develop experimental activities on factors influencing reaction rates from an inquiry-based perspective; to propose the use of different representations for students to express what occurs at the submicroscopic level when different factors affect chemical reaction rates.	Biochemistry	2nd year of upper secondary education
A5	To investigate the contribution of a didactic sequence containing experiments designed within an inquiry-based approach contextualized in the regional scenario of "wildfires," for basic concepts required for the study of thermochemistry.	Chemical Kinetics	2nd year of upper secondary education
A6	To examine students' prior knowledge about separation of mixtures processes and, based on the data obtained, to develop an investigative experimental activity.	Separation of Mixtures	1st year of upper secondary education
A7	To design a didactic sequence with an inquiry-based approach for 3rd-year upper secondary students, addressing the topic "Solutions" in its qualitative and quantitative aspects, in preparation and application in a hydroponic school garden.	Solutions	3rd year of upper secondary education
A8	To investigate the use of online laboratories in chemistry teaching, as well as to select and apply tools in upper secondary education classes at a public school, integrated into an inquiry-based didactic sequence.	Materials and Chemical Bonding	1st year of upper secondary education
A9	To present the contributions of a didactic sequence with an inquiry-based focus for chemistry teaching, highlighting the practical and experimental moments developed with 3rd-year upper secondary students.	Polarity and Separation of Mixtures	3rd year of upper secondary education
A10	To analyze the characteristics associated with investigative and scientific attitudes	Chemical Reactions,	3rd year of upper

	triggered in a face-to-face Interactive Learning Environment (ILE).	Combustion, and Physical Transformations of Matter	secondary education
A11	community, contributing to reflections on praxis related to chemistry and technology teaching and their interdisciplinary relationships, through classroom activities using condoms as a technological artifact.	Characteristics and properties of matter; polymers; pure substances and mixtures	1st year of upper secondary education
A12	To use inquiry-based approaches to enable students to construct and organize their ideas about the constitution of matter.	O estudo do átomo: matéria, modelos, elementos e massa, radioatividade e contemporaneidade	1st year of upper secondary education
A13	To study different types of reactions using oxidized copper coins and household commercial products, to observe the effect of temperature on a reaction, and to discuss the role of chemical equilibria in the efficiency of the proposed cleaning methods.	Chemical Equilibrium	*
A14	To present an inquiry-based experimental methodology for building homemade batteries using lemons and potatoes, aimed at fostering an active, collaborative, and interactive student, acting alternately in offline and online environments.	Introduction to chemical equilibrium, chemical kinetics, and types of chemical reactions	3rd year of upper secondary education
A15	To describe the implementation and analysis of the results of a didactic intervention, with a STS-focused approach, related to advanced oxidative processes in a 3rd-year upper secondary class.	Electrochemistry	3rd year of upper secondary education
A16	To propose the creation of a biodigester prototype, aiming to associate practical activities with contextualization and the concepts addressed in the classroom.	Organic reactions and chemical kinetics	2nd year of upper secondary education
A17	To understand how students from two upper secondary classes at a public school deal with the concepts of acids and bases after using an inquiry-based didactic sequence.	Thermochemistry	2nd year of upper secondary education
A18	To engage students in solving a problem related to a natural phenomenon and to develop skills corresponding to scientific work.	Acids and Bases	2nd year of upper secondary education

A19	To analyze how an experimental activity on homogeneous and heterogeneous mixtures can enable students to construct scientific concepts.	Chemical element: Iron	1st year of upper secondary education
A20	To recognize positive and negative aspects and promote a reflective process among future teachers regarding their classroom practice.	Substances and Mixtures	3rd year of upper secondary education
A21	To develop an inquiry-based didactic experiment in accordance with the assumptions of Inquiry-Based Teaching (IBT), using a digital camera as a teaching tool to record and monitor the experiment.	Instrumentation; Laboratory Practices	2nd year of upper secondary education
A22	To use the Mariana disaster as a generative theme for a STSE-based approach, focusing on water analysis to facilitate chemistry teaching and learning among students of regular technical upper secondary education at IFRJ.	Chemical reactions: rusting	1st year of upper secondary education
A23	To analyze the contributions and implications of a study that used investigative experimentation within an STS approach to teach chemical concepts through a socioscientific theme involving air quality and atmosphere: acid rain.	Solutions, mixtures, and pH	1st and 2nd years of upper secondary education
A24	To evaluate whether there is a significant change in the experimental group's ability to design experiments, compared with the control group's scores, considering tasks that measure Disciplinary Content Knowledge (DCK).	Inorganic functions, chemical reactions, chemical bonding, and solubility	Upper secondary education
A25	To examine how students' actions carry out the operations involved in the practice of planning investigations.	Chemical Kinetics	1st and 2nd years of upper secondary education

*Article A13 presents a discussion of the experiment.

Source: Prepared by the authors (2022).

Among the 25 articles analyzed (Table 03), 11 involved students from the 1st year, ten from the 2nd year, and ten also included students from the 3rd year of upper secondary education. This indicates that, regarding the distribution of studies on inquiry-based teaching involving the discipline of chemistry at this level of education, there is a certain balance in the number of studies across grades/years.

The reading of the 25 articles also revealed that the inquiry-based approach is strongly articulated with other teaching perspectives, making use of teaching strategies such as experimentation, Science–Technology–Society (STS), problem situations or problem-based approaches, and the use of videos as instructional resources.

For example, there is a strong relationship between investigative activities and the use of problem situations. Articles A1–A6, A8–A12, A14, A17, A18, and A21

refer to the problem as an introductory and motivating element for the investigative process. According to Carvalho (2009), the problem can be considered an introductory activity in inquiry-based teaching, either designed by the teacher or articulated with informational materials, as in A5, which used a news report, and in A6, which employed a newspaper headline. It is important to consider this premise, since problems place students in an active role in the search for answers and, along this path, enable the construction of school scientific knowledge (Silva; Sá; Batinga, 2019).

Article A13 proposes, as its research objective, the design and discussion of an experiment using only materials readily available in the kitchen, characterized by easy access and low cost. It refers to an experience report, configured as an experimental sample, which can be used by teachers in the classroom to investigate topics related to oxidative processes and chemical equilibrium (the chemistry contents addressed in the report). Such a proposal may encourage students to develop investigative attitudes (Carlson; Humphrey; Reinhard, 2003) in chemistry classes, as students are stimulated to engage in activities with the potential to promote understanding of chemical phenomena and concepts in real-life contexts.

Articles A1, A3–A5, A7–A11, A15, and A17–A24 make use of investigative experimental activities either as a single stage or as an integral part of a teaching and learning sequence. This aspect highlights the association between experimental activities and inquiry-based teaching, converging with studies by Oliveira (2010), who states that investigative experimentation enables students to research, plan, carry out activities, propose and discuss explanations, and solve problems.

Articles A22 and A3 engage with the Science–Technology–Society–Environment (STSE) perspective, which is configured as a pedagogical approach that seeks to establish connections with economic, social, political, cultural, environmental, and technological aspects, aiming to develop students' critical thinking so that they may become transformative agents in society (Cavalcante; Teixeira; Marcelo, 2019).

Despite the limited number of studies that encompass the intersection between STSE and inquiry-based teaching (A5, A11, and A22), these works seek to contextualize chemistry content by drawing on current topics with wide media coverage, such as the regional scenario of wildfires (A5), condoms as a technological artifact (A11), and the environmental disaster that occurred in Mariana, Minas Gerais (A22). These aspects align with Sampaio and Rotta (2012), who emphasize that contextualization plays a key role when applied both before and after the problematization of knowledge and the construction of ideas and theories, contributing to students' engagement in the learning environment and enabling meaningful learning.

Articles A7 and A18 seek to integrate chemistry content with biology, while article A8 articulates knowledge from chemistry and physics in an empirical proposal used in investigative activities. In these cases, the introduction of the principle of interdisciplinarity in the knowledge construction process can be observed. According to Goldman (1979), an interdisciplinary perspective on reality allows students to better understand the relationship between the whole and its

constituent parts. Thus, the interdisciplinary approach represents a way to integrate different areas of scientific knowledge and address complex problems.

The use of inquiry-based instructional sequences or didactic sequences containing investigative activities was recurrent in several of the analyzed articles. It is important to emphasize that articles A10, A18, A20, A22, and A25 adopt theoretical frameworks related to teaching sequences or instructional stages and include at least one investigative activity in their methodological structure. This aspect is relevant because, according to Zabala (1998), inquiry-oriented didactic sequences foster the investigative character of the teaching and learning process.

School scientific concepts were studied with the aim of enabling students to construct meaning through activities involving problematization, hypothesis formulation, data collection, and the systematization of knowledge. These characteristics were mentioned in articles A4, A7, A8, A9, A17, and A23, highlighting the need to establish connections between students' prior knowledge and the new knowledge to be learned, beginning with the formulation of hypotheses by research participants and through the development of systematic activities along the investigative pathway (Carvalho, 2013).

Regarding the contents addressed, articles A6, A8–A12, A17, A19, A21, A23, and A25 refer to topics studied within the scope of general and inorganic chemistry, such as separation of mixtures and chemical reactions. Articles A4, A5, A7, A11–A16, A22, and A24 address topics commonly associated with physical chemistry, such as chemical kinetics, which is discussed in articles A4 and A24. A significant number of studies (A6, A8, A10, A18, A20, and A22) focus on general chemistry contents typically taught in the first year of upper secondary education, which address elementary foundations of chemistry and are essential for teaching and learning other contents studied later throughout upper secondary education. This finding corroborates Gagliardi (1988), who states that concepts related to substances and mixtures (A23, A20, A11, and A9) are considered structuring within the meaning-making process and demonstrate strong relevance, as they occupy a substantial portion of the school chemistry curriculum. Therefore, it is necessary for students to understand these concepts in order to facilitate the appropriation of many contents addressed subsequently (Gagliardi, 1988).

The analyzed articles addressed purposes of inquiry-based teaching as proposed by Pérez (1993), specifically: (1) providing students with the opportunity to recognize a problem and use strategies to propose solutions; (2) making use of observations; (3) collaborating in groups during the planning and execution of activities; (4) actively participating in debates, formulating arguments and respecting peers' ideas; (5) conducting laboratory work with order, cleanliness, and safety; (6) adopting a critical attitude; and (7) producing written records of the results obtained, using appropriate language correctly and approximating scientific discourse.

Although articles A1, A3–A5, A7–A11, A15, A17–A24, and A25 employ investigative experimentation that addresses purpose (6), only in articles A1, A3, A24, and A25 did students assume the phase of planning the experiments. This aspect relates to the degree of openness of investigative activities discussed by Wellington (2000), which involves the roles of students and teachers, as well as the type of activity. However, the fact that students do not plan all experiments within an investigative process does not negate the investigative nature of the activity.

Depending on the stages involved, the teacher may assume a more active role, which is directly related to the complexity of the investigation and students' maturity within this process.

Articles A4–A9, A17, A18, A21, and A23 cite Carvalho (2009; 2011) as a reference in their theoretical foundation, with emphasis on the stages of inquiry-based teaching proposed by this author. This does not mean that the other articles did not provide guidance regarding the stages of development or the implementation of this pedagogical approach, including its activities and interventions. Articles A12, A14, and A19 cite Azevedo (2004) to discuss the objectives of inquiry-based teaching in the classroom. According to this author, such teaching consists of encouraging students to think, reflect, debate, justify their ideas, and apply the knowledge constructed to new situations.

In summary, some elements identified in the analysis of methodological aspects in articles involving inquiry-based teaching in the discipline of chemistry can be highlighted:

1. There was a balanced distribution of participants across the three grades/years of upper secondary education in the studies analyzed;
2. The contents most frequently studied in the research belong to the field of physical chemistry;
3. The objectives most commonly present in inquiry-based teaching proposals, which align with the purposes outlined by Pérez (1993), were: "providing students with the opportunity to recognize a problem and use strategies to propose solutions," "adopting a critical attitude," and "producing written documents on the results obtained, using appropriate language correctly and approximating scientific discourse";
4. The teaching strategies most frequently employed in inquiry-based teaching proposals were those that used problems as a starting point for investigative experimentation.

FINAL CONSIDERATIONS

This study aimed to identify theoretical and methodological aspects present in research that addresses inquiry-based teaching in the discipline of chemistry within the context of upper secondary education. Inquiry-based teaching is conceived as a pedagogical approach in the studies analyzed. It was found that the highest number of publications on this topic occurred in 2018 and 2019, while the lowest number was identified in 2017. Two articles were published in international science education journals and four in chemistry education journals, indicating the potential to expand the number of publications on inquiry-based teaching in international journals within these fields. Eight articles were published in national journals in the field of science education and eleven in chemistry education journals. Evidence of a research gap concerning inquiry-based teaching in relation to organic chemistry content was identified.

Elements of inquiry-based teaching were identified in research conducted in the discipline of chemistry at the upper secondary level, including: conceptualization, purposes, methodological stages, teaching strategies,

instructional principles such as contextualization and interdisciplinarity, as well as articulations with other teaching perspectives, for example, didactic sequences, the Science–Technology–Society–Environment (STSE) approach, problem-based strategies, and experimentation. The possibility of developing further research involving the articulation between inquiry-based teaching and the STS perspective was identified, since only three articles focused on this approach.

Methodological aspects such as research objectives, themes, chemistry contents addressed, and participants were identified in the analyzed articles. The bibliographic and methodological aspects represent specific characteristics that, taken together, reflect to some extent the systematization of research involving inquiry-based teaching between 2016 and 2020 in the field of chemistry education. Finally, this study may contribute to the dissemination and delineation of new research on this topic that seeks to introduce investigative processes into the teaching and learning of chemistry.

O ENSINO POR INVESTIGAÇÃO NO COMPONENTE CURRICULAR DE QUÍMICA NO ENSINO MÉDIO

RESUMO

Este trabalho apresenta uma revisão de literatura que tem por objetivo identificar aspectos teóricos e metodológicos presentes em pesquisas que discorrem sobre o ensino por investigação, em especial, na disciplina de química, no contexto do ensino médio. Para isso, foram analisados artigos sobre essa temática publicados em periódicos nacionais e internacionais na área de ensino de ciências, no período de 2016 a 2020. O estudo é de caráter qualitativo com relação à abordagem dos dados. Foram encontrados 25 artigos sobre essa temática para o estudo de conteúdos de química, com predominância na área de físico-química. Os resultados indicam os periódicos, títulos, objetivos e participantes das pesquisas, ano da publicação e as estratégias/recursos didáticos, revelando elementos e características das pesquisas que versam acerca do ensino por investigação. As finalidades e etapas inerentes à temática pesquisada foram contempladas na maioria dos trabalhos. Diversas estratégias de ensino foram adotadas para promover atividades investigativas, em especial, o uso de problemas e a experimentação. Espera-se contribuir com a sistematização e divulgação de pesquisas sobre o ensino por investigação na área de ensino de química no âmbito do ensino médio.

PALAVRAS-CHAVE: Ensino de Química. Experimentação. Problemas. Sequência didática.

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Mailing address: Danylo David de Lima Silva - danylodavidlima@gmail.com