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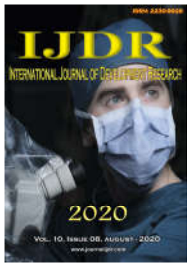

RESEARCH ARTICLE OPEN ACCESS

CRITICAL THINKING IN SCIENCE EDUCATION PUBLICATIONS: THE RESEARCH CONTEXTS

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ABSTRACT

This article presents a literature review on critical thinking in Science Education, in articles published in the period (2010-2019). The objectives were: to identify articles involving critical thinking in Science Education; and to characterize the research contexts in which critical thinking was present in the articles. The analytical procedures were performed from the stages of the systematic literature review, described by Okoli (2015) and from the assumptions of content analysis of Bardin (2011). The articles were selected from the ERIC- Education Resources Information Center database and the results show a moderate number of articles involving this theme (60 articles). Through the analysis, the articles were grouped into 8 categories (C1-C8) that express the different research contexts in which critical thinking is presented in the articles. Such contexts are related to the elaboration and/or investigation of teaching proposals that promote critical thinking; investigations of the ideas and/or skills of students and/or teachers regarding critical thinking; theoretical studies; and studies that investigate the relationship between assessment and critical thinking. Such results point to a trend in research that addresses critical thinking and opens up possibilities for new studies that explore other contexts that have not been investigated yet.

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INTRODUCTION

Critical thinking is a skill considered essential in the educational and scientific context, but also in the life of the citizen inserted in a contemporary society present with technologies and new tools that facilitate everyday life (AMORIM; SILVA, 2014). According to the research by Marsh (2013) in which more than 500 articles are reviewed, critical thinking is universally described as important, but its meaning is not yet fully clarified, because it has pluralist characteristics in the various facets that define it (AMORIM; SILVA, 2014).In the school environment, the term is not clear, especially by teachers, although formulators of educational policies claim that critical thinking is one of the skills to be developed in the learning process, as well as the curriculum content (VINCENT-LANCRINI *et al*., 2019).The Organization for Economic Cooperation and Development (OECD), in a survey in partnership with 11 countries, brought together a network of schools with the objective to approach and share experiences of activities carried out with teachers and students on critical thinking and creative thinking. One of the factors that motivated this engagement by countries to participate in the research was the debate of the organization itself regarding the future of work, since critical thinking is a skill that is hardly capable of being automated. In addition, it is responsible for contributing to social well-being and can be seen as one of the pillars of democracy (VINCENT-LANCRINI *et al*., 2019). For Tenreiro-Vieira (2004), there are many reasons to consider critical thinking relevant at school, since students have the right to develop the ability to evaluate beliefs, ideas and values in order to not passively accept information. Thus, students become autonomous from their conscience, in decision making and are able to deal with the challenges of modernity and the technoscientific advances.

Given this investigative context, the objectives of this article are to:

- Identify articles that address critical thinking in Science Education.
- Characterize the research contexts in which the perspective of critical thinking is present in these articles.

Thus, the research questions that guided this investigation were:

- What has been published about critical thinking in Science Education?
- What are the research contexts in which the critical thinking perspective is present?

Therefore, this study brings results of a literature review of articles published in the period of 2010 to 2019 (a decade), which involve the theme critical thinking in Science Education in order to characterize them regarding the contexts in which critical thinking is studied and presented by the authors.

THEORETICAL FOUNDATION

Lopes, Silva, &Morais (2018), as well as other research (MARSH, 2013; AMORIM & SILVA, 2004; VINCENT-LANCRIN *et al*., 2019) state that there are several understandings for the term critical thinking, not that this means there is a divergence between these definitions, but a wide edification in the dimensions in which these meanings are found. However, with regard to its importance for facing the challenges of human life and the development of a democratic society in a modern and technological context, the different approaches are in agreement.Marsh (2013) and Carbogim*et al*. (2016) cite that critical thinking has three main traditions: philosophical, psychological and educational. In general terms, Ennis (1991), defines it as rational and reflective thinking, centered on deciding what to believe or what to do. Thus, its use in a scientific atmosphere based on rationality and logic enables the consequences of decision making and argumentative coherence. In this way, the notion and the need to develop such competences of students linked to the most diverse aspects of knowledge emerges (TENREIRO-VIEIRA, 2004).Vincent-Lancrini*et al*. (2019) argued that critical thinking is usually linked to the dialectical method of Socrates and his followers whose discourse is based on the search for truth by raising and questioning ideas and building hypotheses. Skepticism in Philosophy treated the concept of critical thinking with greater rigor, being considered the essence of human knowledge.In the field of Education, Dewey contributed to the transposition of the term, since many researchers, including Ennis, Facione and McPeck, anchored themselves in the movement of critical thinking of this philosopher to propose reflections on the educational system (VINCENT-LANCRINI *et al*., 2019). According to Marsh (2013), there is a concern and interest in how to promote critical thinking in students and what will be their feedback later, as citizens and as professionals in the job market.Lopes, Silva, &Morais (2018) comment on some congruent aspects of the multifacets of critical thinking, such as the development of logical reasoning, the ability to argue, metacognition and decision making. In addition, there are researchers who designate connections between critical thinking and creative thinking, since the two concepts are linked and can be developed together. Thinking critically requires a mobility of cognitive and creative resources and, therefore, working with these two skills at school in an integrated manner is a proposal that has been gaining strength (TENREIRO-VIEIRA, 2004; VINCENT-LANCRINI *et al*., 2019).Amorim& Silva (2014) found that, from the perspective of education, it is possible to observe two aspects of critical thinking in which, the first suggests implementing a type of specialized incentive that incorporates the development of strategies related to critical thinking and the second, the insertion of the competence listed in the other subjects of curriculum. Finally, they conclude that, in the midst of the advantages and disadvantages of the proposals, an alternative is to work together with both approaches.

METHODOLOGY

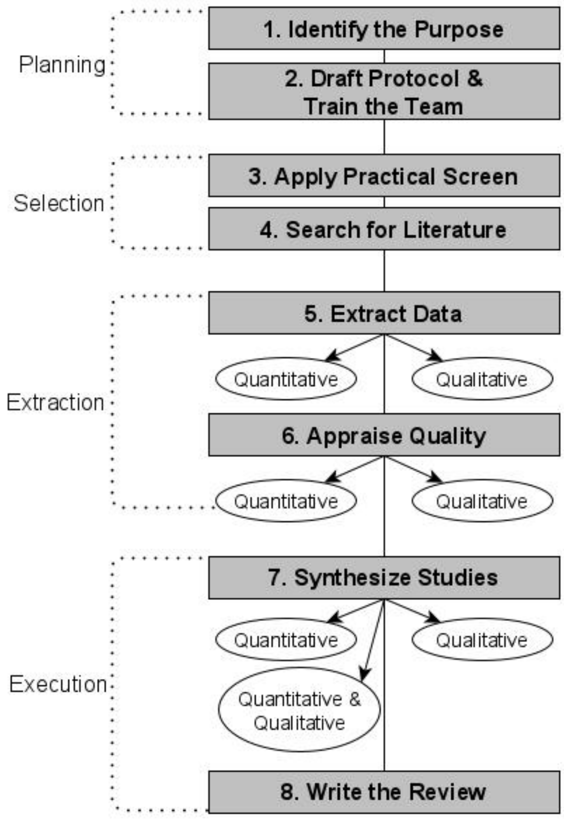
For Fink (2005) a systematic literature review is an orderly, explicit, comprehensive and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded works produced by researchers and scholars. A systematic review can be carried out in order to describe the knowledge available for professional practice; to identify efficient designs and techniques; to identify experts in a given field; and to identifying unpublished sources (FINK, 2005).Okoli (2015) presents a guide for the development of a systematic literature review and describes, in detail, eight steps to ensure a rigorous literature review that comprehensively summarizes and discusses the existing literature (Figure 1).

Each step is described below:

1) **Identify the purpose** - The first step requires the reviewers to clearly identify the purpose of the review and the intended goals. This is necessary for the review to be transparent to readers;
2) **Draft protocol and train the team** - For any review that employs more than one reviewer, the reviewers need to be clear and agree on the procedure they will follow. This requires a written and detailed protocol, as well as an instruction so that all reviewers have consistency in how they will perform the review;
3) **Apply a practical screen** - This step requires reviewers to be transparent about which studies they have considered for the review and which ones they have eliminated (a much needed part of any literature review). For excluded studies, reviewers must present their practical reasons for not considering them;
4) **Search for literature** - Reviewers need to be transparent and clear when describing the details of the literature search and need to explain and justify how they ensured the scope of the research;
5) **Extract data** - After the reviewers have identified all the studies that should be included in the review, it is necessary to systematically extract the information from each study;
6) **Appraise quality** - At this point, reviewers need to explain the criteria that were used to exclude documents of insufficient quality;

7) **Synthesize studies** - This step involves combining the facts extracted from the studies using appropriate techniques, whether quantitative, qualitative or both;
8) **Write the Review** - In addition to the standard principles to be followed when writing research papers, the process of a systematic literature review needs to be reported in sufficient detail so that other researchers can independently reproduce the results of the review (OKOLI, 2015).

The 8 stages, proposed by Okoli (2015), which were conducted in this investigation, are described next. In this study, step 1 consisted of formulating the research objectives and problems, both presented in the introduction. Step 2 consisted of preparing the protocol for the review with the aim of detailing the stages of the study.



Source: extracted and adapted from Okoli (2015)

Figure 1 - Guide to the development of a systematic literature review

Step 3 consisted of applying the filters, the exclusion criteria, and the practical reasons for these referrals, and step 4 consisted of the search itself. For this research, the articles were selected from the database ERIC- Education Resources Information Center[1], an online digital library of education information and research. The search was carried out by using the terms "critical thinking" and "science education" in the searchbar and considering open access articles; which were peer-reviewed; and that had been published in the last decade (2010-2019). This first search generated 119 results.In order to refine the search, the following exclusion criteria were adopted: articles from other disciplinary areas (ex: English Teaching, Engineering, Information Sciences, Social Sciences, Accounting, Library Science, Art, History and Economics); unavailability of free online access; non-periodical articles (conference papers, book chapters); and duplication of results. Education articles were only considered if they were published in journals in the field of Science Education, due to the possible scope and impact that such articles would have on readers in the Science Education field. In order to check the subject area, the title, the journal name and, when necessary, the abstract and keywords were read. This procedure was used in order to maintain the representativeness of the *corpus*. These exclusion criteria reduced the results to 63 articles. Thus, at that time, 56 articles were excluded.Step 5 consisted of systematic extraction of the information. For that, an Inventory was filled out for each article, as followed in other similar studies. This inventory was part of the "Protocol for review", prepared earlier in step 2, from which relevant aspects from each article were selected and transfered to the inventory - authors, year of publication; title; periodical; objectives; level of education; knowledge area; excerpts containing the expression "critical thinking" and theoretical references of critical thinking. To fill in the item "excerpts containing the expression critical thinking" the expression "critical thinking" was searched for in the body of the article; all paragraphs that contained that term were read and transcribed into the inventory.In step 6, the inventories of the articles were read in order to assess the quality and analyze the consistency of the results with the previously established objectives. In this process, 3 articles were excluded, as they only commented on the need for critical thinking to be developed in more research or approaches, not presenting more in-depth analyzes on this topic. Thus, the research *corpus* was reduced to 60 articles.Step 7 consisted of the analysis and synthesis of the inventories, with the objective of characterizing the research contexts in which the perspective of critical thinking was presented. The analytical movements were performed according to Bardin's Content Analysis (2011), defined as a "set of communication analysis techniques" (p. 37), which has as one of its main objectives the inference of knowledge related to production conditions of the message. Bardin (2011) defines Content Analysis as:

> A set of communication analysis techniques aiming to obtain, by systematic and objective procedures for describing the content of messages, indicators (quantitative or not) that allow the inference of knowledge related to the production/reception conditions (inferred variables) of these messages (p. 48, our translation).

Content Analysis has three stages: 1) *Pre-analysis*; 2) *The exploration of the material*; 3) *Treatment of results, inference and interpretation*. In the *pre-analysis*, the initial ideas are organized in order to make the material operational (BARDIN, 2011). In this study, this step consisted of the first reading, or first contact with the articles. Selection of articles; the elaboration of research objectives and questions; and the preparation of the inventory, were also carried out at this stage.The second stage consisted of the systematic administration of the decisions made previously, guided by the hypotheses and theoretical references previously established. The coding, classification and categorization of articles according to their inventories were also carried out at this stage. The articles were coded from A01-A60 according to the order of presentation of results in the database. Bardin (2011) defines the categories resulting from this analytical and interpretative movement as classes that bring together a group of elements under a generic title according to common

[1]https://eric.ed.gov

characters between the elements. For the categorization, the focuses of each article were considered, with regard to the research contexts of critical thinking. The categories emerged from the approximation of meanings, arising from the analysis of the research contexts of each of the articles. In this process 8 categories emerged. The analyzes were carried out by two researchers, independently, reaching 87% of reliability among the reviewers. In the end, the categorizations were also validated by a third researcher.The third step consisted of inferences and interpretations of the inventories and the presentation of the results of the categorizations of the articles. The discussion of the characteristics of the articles and the research contexts involving critical thinking in Science Education were also carried out at this step.We highlight that the characteristics of the articles involving critical thinking (such as: authors; years of publications; journals; institutions; countries; citations in google scholar; levels of education; areas of knowledge; main references cited; and the amount of mentions of the term) were presented and discussed in Costa, Obara&Broietti (2020). In the present article, it was decided to focus the analysis and discussions mainly on the research contexts in which the perspective of critical thinking is discussed in the articles.Therefore, step 7 of the Okoli guide (2015) involved the three main phases of Bardin's Content Analysis (2011). Step 8 consisted of writing the article and describing its stages in detail.

RESULTS AND DISCUSSION

Table 1 shows the references and codes of the articles that were analyzed. The article codes were used in this section to discuss the research contexts of critical thinking.In relation to the research contexts to which the articles address critical thinking, 8 categories were identified that accommodated all the analyzed articles. These categories are presented in Table 2.In the following subsections, excerpts from the articles are presented and discussed in order to illustrate the identified categories.

C1: Articles that develop teaching proposals that promote critical thinking

From Table 2, it is noted that 7% (4 articles) were allocated to category C1, that is, articles that develop teaching proposals that promote critical thinking. A01 for example, reported:

> Pre-service chemistry teachers should have the 21st century competence of the critical thinking skill. Unfortunately, the critical thinking skill and self-efficacy level of Indonesian pre-service chemistry teachers is still low. Problem Based Learning (PBL) model and Inquiry model have been implemented widely to improve the critical thinking skills and self-efficacy of pre-service chemistry teachers; however, weaknesses were found such as the need to improve self-efficacy and investigation process based on science process skill. Therefore, innovation was created to develop Scientific Critical Thinking (SCT) Learning Model based on strengths and weaknesses of PBL model and Inquiry model (A01, p. 59).

It is possible to note that A01 implemented the learning model called Scientific Critical Thinking, that is, a teaching proposal to improve teachers' critical thinking skills, as well as their self-efficacies.Also in the C1 category, we present an excerpt from A25:

> Engineering education addresses the development of professional competencies in undergraduates. In this context, the core set of professional competencies includes critical thinking and problem solving, effective communication, collaboration and team building, and creativity and innovation—also known as the four Cs—as well as socio-professional ethics and sustainable development—referred in this paper as the two Ss. While the four Cs were identified by the associates of the American Management Association based on the needs of the society, professional associations, and businesses; this paper proposes the two S extension to ensure that future engineerscontribute to the well-being of individuals and the preservation of life on Earth. It proposes a tangible framework—the 4C2S—and an application method to analyse the contributions made by engineering capstone programmes to the development of these core competencies in future engineering professional (A25, p. 1).

It is noted that A25 aims to implement a structure called 4C2S, which seeks to develop 6 competencies in total: 1) critical thinking and problem solving; 2) effective communication; 3) collaboration and teamwork; 4) creativity and innovation; 5) socio-professional ethics; and 6) sustainable development. In addition to the structure, an application method is proposed to analyze the contributions of engineering programs to the development of these essential skills in future engineering professionals. Because A25 inserted the two extensions S to the four existing Cs, creating a new tangible structure, A25 was allocated to C1 for developing a teaching proposal that promotes critical thinking. Among the different teaching proposals, the articles allocated in C1 sought to implement learning models (A01), innovative didactic structures (A25), tasks associated with the inverted classroom (A26) and laboratory activities (A33), to assist in the promotion or development of critical thinking.The different articles allocated in C1 report as main results that: methodological innovation can serve as a basis for the development of the model for learning critical scientific thinking (A01); the engineering program analyzed is in accordance with the 4C2S structure (A25); the proposed task was effective in motivating critical thinking and getting students to position themselves based on data (A26); and the laboratory activity allowed students to search the literature, carry out statistical analyzes and draw quantitative and causative conclusions (A33).

C2: Articles that investigate the research subjects' critical thinking ideas/skills

Category C2 accommodated 12% (7 articles) of the *corpus*. The articles allocated to this category sought to investigate the ideas, skills and dispositions of the research subjects regarding critical thinking. The research subjects were commonly teachers, preservice teachers and/or students of Basic Education. The authors use the verbs "evaluate", "examine", and "determine" when investigating the critical thinking of the research subjects. An excerpt from A02 is presented for discussion:

Table 1. Codes and references of the 60 articles reviewed in this study

Reference	Code
Rusmansyah, R., Yuanita, L., Ibrahim, M., Isnawati, I., &Prahani, B. K. (2019). Innovative chemistry learning model: Improving the critical thinking skill and self-efficacy of pre-service chemistry teachers. *JOTSE*, *9*(1), 59-76.	A01
Demiral, U. (2018). Examination of Critical Thinking Skills of Preservice Science Teachers: A Perspective of Social Constructivist Theory. *Journal of Education and Learning*, *7*(4), 179-190.	A02
Siburian, J., Corebima, A. D., & SAPTASARI, M. (2019). The Correlation Between Critical and Creative Thinking Skills on Cognitive Learning Results. *Eurasian Journal of Educational Research*, *19*(81), 99-114.	A03
Unlu, Z. K., &Dokme, I. (2017). Science Teacher Candidates' Epistemological Beliefs and Critical Thinking Disposition. *Eurasian Journal of Educational Research*, *17*(72), 203-220.	A04
Akgun, A., &Duruk, U. (2016). The Investigation of Preservice Science Teachers' Critical Thinking Dispositions in the Context of Personal and Social Factors. *Science Education International*, *27*(1), 3-15.	A05
Hussin, W. N. T. W., Harun, J., &Shukor, N. A. (2019). Online Interaction in Social Learning Environment towards Critical Thinking Skill: A Framework. *Journal of Technology and Science Education*, *9*(1), 4-12.	A06
Kopzhassarova, U., Akbayeva, G., Eskazinova, Z., Belgibayeva, G., &Tazhikeyeva, A. (2016). Enhancement of Students' Independent Learning through Their Critical Thinking Skills Development. *International Journal of Environmental and Science Education*, *11*(18), 11585-11592.	A07
Samanci, N. K. (2015). A Study on the Link between Moral Judgment Competences and Critical Thinking Skills. *International Journal of Environmental and Science Education*, *10*(2), 135-143.	A08
Bati, K., &Kaptan, F. (2015). The Effect of Modeling Based Science Education on Critical Thinking. *Educational Policy Analysis and Strategic Research*, *10*(1), 39-58.	A09
Fettahlıoğlu, P., &Kaleci, D. (2018). Online argumentation implementation in the development of critical thinking disposition. *Journal of Education and Training Studies*, *6*(3), 127-136.	A10
Vieira, R. M., Tenreiro-Vieira, C., & Martins, I. P. (2011). Critical thinking: Conceptual clarification and its importance in science education. *Science Education International*, *22*(1), 43-54.	A11
Raikou, N., Karalis, T., &Ravanis, K. (2017). Implementing an Innovative Method to Develop Critical Thinking Skills in Student Teachers. *ActaDidacticaNapocensia*, *10*(2), 21-30.	A12
Sadhu, S., &Laksono, E. W. (2018). Development and Validation of an Integrated Assessment for Measuring Critical Thinking and Chemical Literacy in Chemical Equilibrium. *International Journal of Instruction*, *11*(3), 557-572.	A13
Demir, S. (2015). Perspectives of Science Teacher Candidates Regarding Scientific Creativity and Critical Thinking. *Journal of Education and Practice*, *6*(17), 157-159.	A14
Akcay, H., Kapici, H. O., &Yager, R. E. (2017). Using Newspapers and Advertisement as a Focus for Science Teaching and Learning. *Universal Journal of Educational Research*, *5*(1), 99-103.	A15
Velez, J. J., Lambert, M. D., & Elliott, K. M. (2015). Perceptions of Critical Thinking, Task Value, Autonomy and Science Lab Self-Efficacy: A Longitudinal Examination of Students' CASE Experience. *Journal of Agricultural Education*, *56*(2), 204-216.	A16
McMillan, C., Loads, D., & McQueen, H. A. (2018). From students to scientists: The impact of interactive engagement in lectures. *New Directions in the Teaching of Physical Sciences*, (13).	A17
Aljaraideh, Y. (2019). Students' perception of flipped classroom: A case study for private universities in Jordan. *JOTSE: Journal of Technology and Science Education*, *9*(3), 368-377.	A18
Trnova, E. (2014). IBSE and Creativity Development. *Science Education International*, *25*(1), 8-18.	A19
Applebaum, M. (2015). Activating Pre-Service Mathematics Teachers' Critical Thinking. *European Journal of Science and Mathematics Education*, *3*(1), 77-89.	A20
Parahakaran, S. (2017). An Analysis of Theories Related to Experiential Learning for Practical Ethics in Science and Technology. *Universal Journal of Educational Research*, *5*(6), 1014-1020.	A21
Chun, M. S., Kang, K. I., Kim, Y. H., & Kim, Y. M. (2015). Theme-Based Project Learning: Design and Application of Convergent Science Experiments. *Universal Journal of Educational Research*, *3*(11), 937-942.	A22
Upahi, J. E., Issa, G. B., &Oyelekan, O. S. (2015). Analysis of Senior School Certificate Examination Chemistry Questions for Higher-Order Cognitive Skills. *Cypriot Journal of Educational Sciences*, *10*(3), 218-227.	A23
Trna, J. (2014). IBSE and Gifted Students. *Science Education International*, *25*(1), 19-28.	A24
Malheiro, B., Guedes, P., Silva, M. F., & Ferreira, P. (2019). Fostering professional competencies in engineering undergraduates with eps@ isep. *Education Sciences*, *9*(2), 119.	A25
Zimeri, A. M. (2016). A Flipped Classroom Exercise to Teach Undergraduates to Critically Think Using Primary Scientific Literature. *International Journal of Environmental and Science Education*, *11*(12), 5396-5403.	A26
Sopegina, V. T., Chapaev, N. K.,&Simonova, M. V. (2016). Integration of Pedagogical and Technological Knowledge in Forming Meta-Competencies of a Modern Worker. *International Journal of Environmental and Science Education*, *11*(15), 7836-7846.	A27
Dilli, R. (2016). Conducting Museum Education Activities within the Context of Developing a Nature Culture in Primary School Students: MTA Natural History Museum Example. *International Journal of Environmental and Science Education*, *11*(2), 75-84.	A28
Bustamante, A. S., Greenfield, D. B., &Nayfeld, I. (2018). Early childhood science and engineering: Engaging platforms for fostering domain-general learning skills. *Education Sciences*, *8*(3), 144.	A29
Mangiante, E. S. (2013). Planning science instruction for critical thinking: Two urban elementary teachers' responses to a state science assessment. *Education Sciences*, *3*(3), 222-258.	A30
Sofroniou, A., &Poutos, K. (2016). Investigating the effectiveness of group work in mathematics. *Education Sciences*, *6*(3), 30.	A31
Kayumova, L. R., &Morozova, M. A. (2016). Using the Technology of Critical Thinking Development (CTD) as a Means of Forming Competencies of Students Majoring in" Life Safety". *International journal of environmental and science education*, *11*(8), 2113-2122.	A32
Song, P. (2014). A handful of bacteria: A simple activity that engages students to think and write like a scientist. *Journal of Technology and Science Education*, *4*(1), 3-11.	A33
Qureshi, S., Bradley, K., Vishnumolakala, V. R., Treagust, D., Southam, D., Mocerino, M., &Ojeil, J. O. S. E. P. H. (2016). Educational reforms and implementation of student-centered active learning in science at secondary and university levels in Qatar. *Science Education International*, *27*(3), 437-456.	A34
Akhmetov, A. S., Muchkin, D. P., &Utyubayev, E. S. (2016). The Relevance of Finding a Solution to the Problem of Allegations Validation in the Conditions of Legal Culture Formation in Civil Society. *International Journal of Environmental and Science Education*, *11*(10), 3607-3613.	A35

Continue ….

Frey, B. B., Ellis, J. D., Bulgreen, J. A., Hare, J. C., & Ault, M. (2015). Development of a Test of Scientific Argumentation. *Electronic Journal of Science Education*, *19*(4), n4.	A36
Corlu, M. A., &Corlu, M. S. (2012). Scientific Inquiry Based Professional Development Models in Teacher Education. *Educational Sciences: Theory and Practice*, *12*(1), 514-521.	A37
Smith, T. K. (2014). Elementary science instruction: Examining a virtual environment for evidence of learning, engagement, and 21st century competencies. *Education Sciences*, *4*(1), 122-138.	A38
Richardson, N., Tooker, P. A., &Eshleman, A. (2014). Core sciences in first-year learning communities. *Learning Communities Research and Practice*, *2*(1), 4.	A39
Franco, Y. (2013). Building a Community of Inquirers in Your Classroom: Learning from Our Global Colleagues. *Electronic Journal of Science Education*, *17*(4), n4.	A40
Kizilaslan, A., Sozbilir, M., &Yasar, M. D. (2012). Inquiry Based Teaching in Turkey: A Content Analysis of Research Reports. *International Journal of Environmental and Science Education*, *7*(4), 599-617.	A41
Christensen, D. R., &LaRoche, A. (2012). Using Stable Isotopes of Carbon and Nitrogen to Evaluate Trophic Interactions in Aquatic Environments. *Bioscene: Journal of College Biology Teaching*, *38*(1), 22-27.	A42
Ketpichainarong, W., Panijpan, B., &Ruenwongsa, P. (2010). Enhanced learning of biotechnology students by an inquiry-based cellulase laboratory. *International Journal of Environmental and Science Education*, *5*(2), 169-187.	A43
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Rillero, P. (2016). Deep Conceptual Learning in Science and Mathematics: Perspectives of Teachers and Administrators. *Electronic Journal of Science Education*, *20*(2), 14-31.	A45
Zion, M., &Mendelovici, R. (2012). Moving from structured to open inquiry: Challenges and limits. *Science Education International*, *23*(4), 383-399.	A46
Viro, E., &Joutsenlahti, J. (2018). The StarT Project Competition from the Perspective of Mathematics and Academic Literacy. *Education Sciences*, *8*(2), 67.	A47
Mirzagitova, A. L., &Akhmetov, L. G. (2016). Formation of the Professional and Didactic Culture of the Future Teacher. *International Journal of Environmental and Science Education*, *11*(14), 6675-6689.	A48
Kadayifci, H., &Yalcin-Celik, A. (2016). Implementation of Argument-Driven Inquiry as an Instructional Model in a General Chemistry Laboratory Course. *Science Education International*, *27*(3), 369-390.	A49
Taylor, J. C., Tseng, C. M., Murillo, A., Therrien, W., & Hand, B. (2018). Using Argument-Based Science Inquiry to Improve Science Achievement for Students with Disabilities in Inclusive Classrooms. *Journal of Science Education for Students with Disabilities*, *21*(1), 1-14.	A50
Erdogan, I., &Ciftci, A. (2017). Investigating the Views of Pre-Service Science Teachers on STEM Education Practices. *International Journal of Environmental and Science Education*, *12*(5), 1055-1065.	A51
Bagán, H., Sayós, R., &García, J. F. (2015). Skill development in experimental courses. *Journal of Technology and Science Education*, *5*(3), 169-183.	A52
Hynes-Berry, M., & Berry, G. (2014). "Reading an Object": Developing Effective Scientific Inquiry Using Student Questions. *European Journal of Science and Mathematics Education*, *2*(2), 87-97.	A53
Benzer, E. (2015). Exploring the Opinions of Pre-Service Science Teachers in Their Experimental Designs Prepared Based on Various Approaches. *European Journal of Science and Mathematics Education*, *3*(4), 376-389.	A54
Arsal, Z. (2010). The Effects of Diaries on Self-Regulation Strategies of Preservice Science Teachers. *International Journal of Environmental and Science Education*, *5*(1), 85-103.	A55
Guney, B. G., &Seker, H. (2012). The Use of History of Science as a Cultural Tool to Promote Students' Empathy with the Culture of Science. *Educational Sciences: Theory and Practice*, *12*(1), 533-539.	A56
Clark, J. M., Rollins, A. W., & Smith, P. (2014). New methods for an undergraduate journal club. *Bioscene: Journal of College Biology Teaching*, *40*(1), 16-20.	A57
Fessakis, G., &Zoumpatianou, M. (2012). Wikipedia uses in learning design: A literature review. *Themes in Science and Technology Education*, *5*(1-2), 97-106.	A58
Ercan, O., &Bilen, K. (2014). Effect of web assisted education supported by six thinking hats on students' academic achievement in science and technology classes. *European Journal of Educational Research*, *3*(1), 9-23.	A59
Boutte, G., Kelly-Jackson, C., & Johnson, G. L. (2010). Culturally relevant teaching in science classrooms: Addressing academic achievement, cultural competence, and critical consciousness. *International Journal of Multicultural Education*, *12*(2).	A60

Source: the authors

Table 2.Research contexts in which critical thinking is presented in the articles

Categories	Research Contexts	Articles
C1	Articles that develop teaching proposals that promote critical thinking.	A01, A25, A26, A33
C2	Articles that investigate the research subjects' critical thinking ideas/skills.	A02, A04, A05, A08, A14, A16, A20
C3	Articles that investigate the promotion of critical thinking in some teaching proposals.	A03, A06, A09, A10, A12, A27, A30, A31, A32, A38, A49
C4	Articles that discuss critical thinking theoretically.	A07, A11, A48, A56
C5	Articles that investigate the relationship between assessment and critical thinking.	A13, A23, A36
C6	Articles that suggest that certain teaching proposals can promote critical thinking.	A15, A18, A19, A21, A22, A24, A28, A29, A34, A35, A37, A39, A40, A41, A42, A43, A44, A45, A46, A47, A50, A51, A54, A57, A58, A59, A60
C7	Articles that criticize teaching proposals that do not promote critical thinking.	A17, A55
C8	Articles that present the term critical thinking only in the keywords.	A52, A53

Source: the authors

The purpose of this study is to examine the critical thinking skills of preservice science teachers in terms of various variables (gender, grade level, academic grade point average, participation in activities) and their opinions(A02, p. 179).

Thus, A02'sexamines teacher's critical thinking.

A05 sought to determine the dispositions of critical thinking of preservice science teachers and to examine the possible effects of some variables, including personal and social factors.A08 also investigated the critical thinking skills of preservice teachers. Below, the objectives of A08 are presented:

- To determine the moral judgment competences and critical thinking abilities of pre-service primary and biology teachers,

- To determine the relationship between moral judgment competences and critical thinking abilities of pre-service primary and biology teachers,
- To determine the effects of gender, department, and academic performance scores (GPA) on moral judgment competences and critical thinking abilities of pre-service primary and biology teachers (A08, p. 137).

A08 sought to relate the moral judgment and critical thinking of the undergraduates. In addition, the article investigated the effects of different variables under the critical thinking of these research subjects.This category also accommodated articles that investigated the ideas/perceptions of undergraduates or students about critical thinking. An excerpt from A14 is presented for discussion:

> Teachers who can think creatively and critically based on a scientific perspective, and who can see events from different angles occupy an important place in education. Training science teachers who have creative and critical thinking, as well as a scientific perspective, is particularly important for raising future generations who also possess these thinking skills. For this reason, we believe that it is particularly important to assess and determine the level of scientific creativity and critical thinking among science teacher candidates. In this context, the aim of this study was to determine how science teacher candidates assessed their own level of scientific creativity and critical thinking (A14, p. 157).

It is noted that A14 sought to determine how science graduates understand the concepts of scientific creativity[2]and critical thinking. Similarly, A16 examined the perceptions of students enrolled in a specific course about critical thinking, task value, autonomy and self-efficacy in the science laboratory.Among the articles in this category, two sets were identified. A set of articles (A02, A04, A05, A08, A20) that examined the critical thinking skills of the research subjects and another set (A14, A16) that sought to determine how the research subjects understood/perceived critical thinking.Among the results presented by the articles, some can be highlighted: the undergraduate students' critical thinking skills did not show significant differences according to gender, level of education and average academic grades, but there was a significant difference in terms of the activities performed. In addition, the preservice teachers expressed that their family structures and social environments were considered effective in the development of critical thinking (A02). A04 found that female students had more developed epistemological beliefs than male students. Students 'Scale of Epistemological Beliefs (SEB) and California Critical Thinking Disposition Inventory (CCTDI) scores also exhibited a moderate positive correlation and students' epistemological beliefs and critical thinking dispositions did not vary regularly according to class level.

A05's results revealed that the preservice science teachers' critical thinking dispositions are low. Furthermore, there was no significant difference between the scores of the critical thinking dispositions of science teachers according to gender, grade, school and authority at home, different from other variables, such as independent decision-making and receiving academic guidance that showed significant differences. The results of A08 show a positive and statistically relevant relationship between moral judgment and critical thinking of undergraduates. They also noted that gender and department (Chemistry, Physics, Mathematics) had no impact on critical thinking skills, nor on moral judgment.The results of A14 indicated that preservice science teachers did not have a deep understanding or interpretation of the concept of scientific creativity and that their knowledge about critical thinking was insufficient. The results of A16 did not reveal differences in the construct means between the evaluation points. The results of A20 show difficulties in the preservice teachers' ability to analyze possible errors and deal with mental dissonance when faced with contradiction.

C3: Articles that investigate the promotion of critical thinking in some teaching proposals

Category C3 corresponded to 18% (11 articles) of the *corpus*. The articles in this category sought to investigate existing teaching proposals that can promote critical thinking. Below is an excerpt from A06 for discussion:

> The students can enhance critical thinking skills by expressing their opinions, challenging the ideas of others, discussing and collaborating with each other for a solution to a provided problem (Brindley, Blaschke&Walti, 2009). Razzak (2016) reported a number of researches that revealed there are efficient asynchronous tools i.e. threadedmessages in discussion and tasks based on technologies being used for critical thinking enhancement. Thus, to obtain a more meaningful and engaging online discussions and tasks, there is a need to design carefully including having clear instructions, close monitoring and feedback from the instructors to foster critical thinking skills of the students (Hanna, Glowacki-Dudka&Conceicao-Runlee, 2000; Horton, 2000; MacKnight, 2000). Therefore, the research question of this study is, "what are the elements of effective social learning online interaction that promotes critical thinking?" (A06, p. 5).

From the excerpt above it is noted that A06 sought to investigate the elements of online interaction for effective social learning that promotes critical thinking.A09, on the other hand, analyzed the effect of science education based on modeling in the promotion of critical thinking. A06's research questions are presented below:

- Is there a significant difference between experimental groups' critical thinking skills pre-test and post-test scores while using a modeling based science education program with primary school students?
- Is there a significant difference between experimental and control groups' post-test critical thinking skills scores while using a modeling based science education program with primary school students? (A09, p. 44).

Among the articles allocated in C3, there were a variety of teaching proposals that were investigated, such as:*inquiry learning strategies* (A03); *social learning online interaction* (A06); *modeling based science education programs* (A09); technologies (A10, A27, A32); *workshops designed by the*

[2]For the authors, creative thinking and critical thinking are two superior thinking skills that support each other, as they involve the production or selection of ideals based on information, knowledge and logic (Carroll, 2013). Critical thinking is more associated with rational and conscious processes, while creative thinking tends to be associated with irrational factors or unconscious processes (Alghafri and Bin Ismail, 2014).

Transformative Learning through Aesthetic Experience methods (A12);*science instruction* (A30); *group work* (A31); *virtual world curriculum* (A38); *Argument-Driven Inquiry* (A49). In relation to the results, A03's results show that there was a significant correlation between critical thinking skills and creative thinking skills in cognitive learning outcomes. According to A06, developing critical thinking is very difficult without interaction. Thus, online interaction through social learning is designed as an environment for this purpose. The results of A09 show that there was no significant difference between the means of the post-test application of the experimental and control groups, regarding the use ofthe*Modeling Based Science Education Program*. A09 argues that although it is emphasized that the modeling-based approach contributes to the development of students' creativity, it is assumed that this development is not reflected in the critical thinking dimension.The results of A10 show that there was a statistically significant difference in favor of critical thinking of the experimental group, with regard to the use of*teaching technologies and material development course taught through Moodle based online argumentation*.According to A12, the development of critical thinking skills in preservice teachers is evident, regarding the use of*method application for educating adults*.According to A27, the development of meta-competences, such as critical thinking, in *modern worker's training* requires the integration of*pedagogical and production tasks*. The results of A30 suggest that the training and resources of teachers influenced their interpretations about*focus areas on the science assessment inquiry task*. The results of A31 on the effectiveness of group work showed positive results such as deepening students' understanding of the material, as well as discussing the importance of the different proposed solutions.A32 presents descriptions of the experience of the systematic use of different techniques and methods of critical thinking development technology (CTD) for training students. The technology demonstrated a significant increase in some parameters of the experimental group with the control group, with motivational, intellectual and activity indicators. A38's results show measurable learning results, highly engaged and motivated students and observations of student behaviors conducive to science learning at school, such as collaboration, problem solving, critical thinking, *critical inquiry*, global awareness and use of technology. The results of A49 show that the participants' oral and written observations clarify the effectiveness of *Argument-Driven Inquiry*and highlight positive and negative characteristics associated with the model.

C4: Articles that discuss critical thinking theoretically

Category C4 corresponded to 7% (3 articles) of the *corpus*. This category consisted of articles that discussed critical thinking theoretically, without presenting empirical data related to critical thinking. An excerpt from A07 about its focus is shown below:

> The article focuses on the problem of developing students' critical thinking skills, which help them become independent learners. Analysis of research works of educators and scholars enable the authors to reveal qualities, necessary for students to enhance their critical thinking skills and become independent learners. Different points of view on the problem are given (A07, p. 11585).

In this sense, article A07 sought to discuss the development of students' critical thinking skills, which help them become independent learners. For this, the authors highlight the importance of command and teamwork:

> It is considered that development of students' critical thinking skills within framework of their independent work is created through the use of "command or team approach". The command is a small group of people possessing skills of interchange ability, jointly working for implementing the common aim and bearing responsibility before each other for its accomplishment. Command work is an active process of team work in achieving joined goals and objectives (Levin, 2002; Reynolds, 1994) (A07, p. 11589).

Similarly, A48 discusses critical thinking theoretically, more specifically regarding its skills, its purposes and its components, emphasizing the formation of the preservice teachers' professional and didactic culture. In this sense, A48 argues that:

> Professional and didactic culture should be based on critical thinking of the teacher. An indispensable condition for critical thinking is the knowledge of the rules of logic. To learn to think critically for the student is to follow the rules of logic. It is important to master the algorithm of the critical approach to the process of teaching (A48, p. 6685).

A56 discusses critical thinking in the context of the History of Science:

> Cognitive aspects of empathy can be discussed under four main headings. These aspects are; Understanding the Events, Understanding Different Perspectives, Understanding the Tentativeness of the Conclusions, Critical Thinking (Or Perspective Taking) (A56, p. 534).

It is noted that A56 deals with the theme History of Science and how it can be used to promote empathy. According to A56, empathy can be discussed by several aspects, one of them being critical thinking.Article A11 also develops theoretical discussions about critical thinking; however, it seeks to relate critical thinking to other concepts, such as scientific literacy:

> This paper attempts to clarify this concept [critical thinking], evincing its relationship with other concepts such as scientific literacy and to present and discuss a framework for promoting students' critical thinking in science classrooms (A11, p. 43).

A11 presents perspectives and definitions by different authors, such as: Wright (1992), Ennis (1985), Paul (1993), among others and documents about critical thinking, such as the National Research Council (NRC, 1996) and the OECD (2005). The article defends its objective by reporting that although different countries have made attempts to implement critical thinking in the science curriculum, one of the major obstacles to this has been the lack of clarity that teachers have on the subject.

C5: Articles that investigate the relationship between assessment and critical thinking

Category C5 corresponded to 5% (3 articles) of the *corpus*. The articles allocated to this category investigated, studied or discussed the relationship between assessment and critical thinking.Article A13, for example, seeks to develop and validate an integrated assessment tool that measures students' critical thinking and chemical literacy. An excerpt from A13 is presented below for discussion:

> The purposes of this study were to report on the development and validation of an integrated assessment for measuring critical thinking and chemical literacy in 11th grades in chemical equilibrium (A13, p. 559).

According to A13, there is little evidence that instruments are being used to assess critical thinking and chemical literacy, in part, due to the lack of integrated instruments for assessing critical thinking and scientific literacy. In this sense, A13 considers the elaboration of specific assessments for chemistry important. A23 analyzes*Senior School Certificate Examination Chemistry Questions*:

> Whatever form of assessment is employed to measure students' learning, they should include tasks that are authentic, relevant and approximate skills students will need in real-life situations. These skills are well accentuated in the advocacy of the current reforms in science education to develop students' higher-order cognitive skills (HOCS) through question-asking, critical thinking and problem solving (A23, p. 218).

It is noted that A23 does not contain the term critical thinking in its objective, but it does present the term critical thinking when discussing assessment used to measure learning. In this sense, the article seeks to analyze chemistry questions from a*senior school certificate examination*conducted bythe National Examination Council (NECO).A36, on the other hand, developed a scientific argumentation measurement instrument in the classroom. The total score and the subscale of the developed measure correlated moderately with an existing measure of critical thinking. In addition, the article presents the limitations of existing assessments of critical thinking and scientific literacy.The articles allocated to this category presented the term critical thinking in a context related to assessment, either through the elaboration of an assessment to measure critical thinking (A13), or discussions about evaluation and critical thinking (A13, A36). The results of these articles indicate that: integrated assessment has a relatively high validity and reliability. In this way, assessment can be used to measure 13 integrated skills of critical thinking and chemical literacy in chemical equilibrium (A13). The results of A23 show that about 80% of the chemistry questions analyzed in the*senior school certificate examination*conducted by the*National Examination Council* (NECO) require lower-order cognitive skills (LOCS) and 44% of the questions, required factual knowledge. The results of A36, show that the elaborated evaluation provides a total score and subscores that cover the ability to identify statements and "qualifiers" in a statement, the ability to distinguish between a fact of "statement", "opinion" and "data", the ability to distinguish between "authority", "logic" and "theory", that is, constructs related to critical thinking.

C6: Articles that suggest that certain teaching proposals can promote critical thinking

Category C6 contained the largest number of articles, representing 45% of the *corpus* (27 articles). In this category the articles suggest that a specific teaching proposal[3] can promote critical thinking skills. The articles in this category address critical thinking in a more superficial way, focusing more on teaching proposals than on the critical thinking skills promoted in such proposals. These characteristics differentiate the articles in this category (C6) from those in category C3, in which critical thinking skills are discussed in more depth by the authors. Another evidence that helped us in this distinction is that the inventories of articles allocated to category C3 were much more extensive than the inventories of articles of category C6, since in category C6 mentions of the term "critical thinking" appear with a greater frequency throughout the articles.

Following is an excerpt from A15 for discussion:

> Newspapers and advertisements can be used as a context for developing scientific literacy and for promoting the development of critical thinking skills, through questioning, creating flexible course content, and exploring science beyond the classroom (A15, p. 99).

It is noted that A15 presents the term critical thinking in excerpts in which it discusses the use of newspapers and advertisements in science classes. According to A15, these teaching proposals can promote critical thinking. However, A15 does not go into further details on how or why such proposals promote critical thinking skills. Similarly, A18 also states that critical thinking can be a result of a specific teaching proposal:

> Flipped classroom, as an innovative strategy used in higher education, suits the demands of students at a university level, developing their critical thinking and problem-solving skills (A18, p. 368).

We see from this excerpt that A18 considers the inverted classroom as a teaching proposal that can develop critical thinking and problem solving skills.The articles allocated to C6 presented a variety of teaching proposals, as promoters of critical thinking. The teaching proposals mentioned were: newspapers and advertisements (A15); the inverted classroom (A18); scientific inquiry (A19, A26, A37, A40, A41, A46); education for higher order thinking (A21); projects (A22, A47); natural history museums (A28); science and engineering teaching in early childhood (A29); student-centered teaching (A34); the determination of the truth of arguments (A35); a course called Reflective Tutorial (RFT) (A39); laboratory exercises/practices (A42, A43, A54); the integration of multiple dimensions into the curriculum development process (A44); deep conceptual learning (A45); the heuristic approach to scientific writing (A50); STEM teaching (A51); the integration of scientific literature in the classroom (A57); the Wikipedia environment for developing debates (A58); the "six thinking hats" technique (A59); and the demonstration of the interdisciplinary nature of science (A60).We observed that among the teaching proposals cited by the authors, *Scientific inquiry* was the most cited. We also emphasize that the articles allocated to C6 did not have critical thinking as the central focus of their investigations, nor did they discuss in depth aspects related to critical thinking. We emphasize that these

[3]The term teaching proposals was used to maintain a standard, but the authors of the articles also used the terms: models, strategies, interaction, specific courses, programs, tools, technologies, museums, activities, and types of learning.

articles do not bring empirical results or theoretical conclusions about critical thinking specifically.

C7: Articles that criticize teaching proposals that do not promote critical thinking

Category C7 contained 3% (2 articles) of the *corpus*. This category corresponded to articles that criticized specific teaching proposals for not promoting critical thinking. An excerpt from A17 is presented below for discussion:

> The continued use of didactic lectures in university education often leads to the accumulation of superficial knowledge, and does not adequately train students to acquire the skills and attributes required of an effective scientist: critical thinking, an inquiring mind and creativity (A17, p. 1).

It is noted that A17 criticizes the continuous use of expository lectures, stating that this proposal does not allow students to acquire critical thinking, as well as a questioning and creative mind. The following is an excerpt from A55:

> This study aimed to determine the effect of pre-service science teachers' keeping diaries of their study activities on their usage level of self-regulation strategies. At the end of the study, no significant difference was found between the experimental and control groups regarding usage of extrinsic motivation, control of beliefs, self-efficacy, test anxiety, rehearsal, elaboration, organization, critical thinking, peer learning, help seeking strategies. On the other hand, a significant difference in favor of the experimental group was observed, which reported their self-regulation strategies by keeping a diary, regarding the usage of intrinsic motivation, task value, metacognition, time management strategies (A55, p. 95).

A55 investigates the effects of the use of diaries on the self-regulation strategies of preservice science teachers. According to A55 diaries can be used mainly to measure students' self-regulatory behaviors or to monitor the process of developing self-regulation. Despite this, A55 comments that the use of diaries did not produce significant effects regarding the development of critical thinking skills.

Regarding the results pointed out by the articles of C7, A17 found that the use of *active learning lecture strategies*were considered more beneficial than *standard lecturing*. A17 also investigated the use of the "quecture" (an adaptation of the inverted classroom) and found that students did not consider this method as the most useful, despite being the most interactive. The evidence suggests that this resistance results from the need for prior preparation, perceived as an increase in students' workload. A55 argued that the use of diaries to develop self-regulation strategies did not promote a significant difference, in terms of critical thinking, between the control group and the experimental group. Despite this, other advantages of using diaries were noted, such as the development of self-regulation, motivation and time management strategies, for example.

C8: Articles that present the term critical thinking only in the keywords

Category C8 contained 3% (2 articles) of the *corpus*. This category corresponded to articles that presented the term critical thinking only in the keywords.A52, for example, focuses on the development of skills in experimental courses and presents the following keywords: *Cooperatve grouping*, *Critical thinking*, *Laboratory science*, *Lifelong learning*. Despite this, there is no other mention of the term critical thinking in the rest of the article.Similarly, A53 focuses on the development of *effective scientific inquiry*, through student questions and presentes the following keywords: *problem-solving*, *critical thinnking engagement*, *guided inquiry*, *practice standards*. Despite this, there is no other mention of the term critical thinking in the rest of the text.We consider the fact that these articles present the term critical thinking in the keywords and do not treat the theme topic in the body of the article as a contradiction, since the purpose of the keywords is to summarize the main themes of a text, in addition to identifying important ideas and themes to serve as reference to research.

FINAL CONSIDERATIONS

Given the results of this study, we return to our research questions: 1) What has been published about critical thinking in Science Education? 2) What are the research contexts in which the critical thinking perspective is present?

It was possible to identify 60 articles that addressed critical thinking in the field of Science Education. We consider this quantity of articles to be moderate, due to the relationship that the theme has with Science Education and the prominence that the term presents in guiding documents.Regarding the research contexts identified in the analyzed articles, 8 contexts were established related to the following aspects: articles that develop teaching proposals that promote critical thinking (C1); articles that investigate the research subjects' critical thinking ideas/skills (C2); articles that investigate the promotion of critical thinking in some teaching proposals (C3); articles that discuss critical thinking theoretically (C4); articles that investigate the relationship between assessment and critical thinking (C5); articles that suggest that certain teaching proposals can promote critical thinking, however, focus their discussions more on the description of teaching proposals (C6); articles that criticize teaching proposals that do not promote critical thinking (C7); and, finally, articles that present the term critical thinking only in the keywords (C8). In view of the diversity of contexts found, we consider that the results of this review permit a clearer view of *what has been published specifically about critical thinking in Science Education*, and also, *how the authors have discussed this theme*. We also identified the need to conduct more research that has critical thinking as its main focus, as well as possibilities to explore other contexts that have not yet been investigated or haven't been investigated enough.Regarding the percentage of articles distributed in the categories, we found that the research context C6 was the most expressive (45% of the articles) and comprised articles that suggest that certain teaching proposals can promote critical thinking. The articles allocated in this category do not address critical thinking in depth and often the term does not appear in the objectives or in the research questions, being therefore exposed in the discussions, as potential results of the implementation of different teaching proposals, without explaining *how* or *why* such proposals promote critical thinking.

In category C6, we also identified a series of teaching proposals cited by the authors, such as: newspapers and advertisements (A15); the inverted classroom (A18); Scientific inquiry (A19, A26, A37, A40, A41, A46); education for higher order thinking (A21); projects (A22, A47); natural history museums (A28); science and engineering teaching in early childhood (A29); student-centered teaching (A34); the determination of the truth of arguments (A35); a course called Reflective Tutorial (RFT) (A39); laboratory exercises/practices (A42, A43, A54); the integration of various dimensions into the curriculum development process (A44); deep conceptual learning (A45); the heuristic approach to scientific writing (SWH) (A50); STEM teaching (A51); the integration of research literature in the classroom (A57); the Wikipedia environment for developing debates (A58); the "six thinking hats" technique (A59); and the demonstration of the interdisciplinary nature of science (A60). Among the proposals, we observed a trend of *relating inquiry to critical thinking*, since it was the teaching proposal that was most cited by the articles.The high number of articles allocated in this category also shows the need of research that investigates/discusses critical thinking in a more in-depth way, presenting it as a central theme of investigation. C8 (3%) also corroborates this statement, since the articles included in this category present the term critical thinking only in the keywords, without resuming or discussing critical thinking in other moments of the text. Such results show that *critical thinking is still used, sometimes, as an empty or casual term without basing it on theoretical references*.

On the other hand, 52% of the articles were placed in different categories (C1, C2, C3, C4, C5 and C7) that discuss contexts related to the elaboration and/or investigation of teaching proposals that promote critical thinking; investigations of the ideas and/or skills of students and/or teachers about critical thinking; and studies that investigate the relationship between assessment and critical thinking.In this sense, we can observe the recommendation of different guiding documents that suggest mechanisms that prioritize critical thinking as the subjects' skills and the proposals of the articles analyzed in this review. These proposals seek to encourage critical thinking at different levels of education.Based on this research, it is undeniable to affirm the contribution of different areas in an attempt to understand the term critical thinking in its definition. Epistemologically, the multidimensional character allows us to understand that thinking critically is complex and requires cognitive effort to develop. Therefore, conducting a review of scientific articles that discuss this topic, organizing the results in a systematic way helps to reflect on the advances, limitations and implications that they bring to the academic field.*A path that remains to be gone through is research in Science Education with a greater emphasis on critical thinking as its main theme*. Discussing the *how* and *why*critical thinking is promoted in such teaching proposals is not yet clarified in 45% of articles in category C6. Research with critical thinking as its main focus, being presented in research problems and objectives can help expand knowledge about critical thinking and prevent the expression from becoming "for all use", which can empty its meaning, as in category C8.

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