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Pensamento crítico no ensino de Ciências e ensino de Matemática: tendências de pesquisa para 2010-2019

Critical thinking in Science education and Mathematics education: research trends of 2010-2019

Pensamiento crítico en educación Científica y educación Matemática: tendencias de investigación de 2010-2019

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Resumo

Esta pesquisa apresenta uma revisão sistemática da literatura de artigos sobre pensamento crítico em Ensino de Ciências e Educação Matemática. O objetivo é (1) identificar artigos que envolvam pensamento crítico no Ensino de Ciências e Educação Matemática em periódicos internacionais; e (2) identificar as principais características desses artigos, em termos de: autores; anos de publicações; periódicos; instituições dos autores; países; citações; níveis de ensino; área; as principais referências citadas; e o número de menções do termo pensamento crítico. Os procedimentos metodológicos foram realizados de acordo com as oito etapas de Okoli (2015) para a realização de uma revisão sistemática e a Análise de conteúdo de Bardin (2011). O banco de dados utilizado foi o Centro de Informações sobre Recursos Educacionais (ERIC), do qual foram analisados 63 artigos publicados entre os anos 2010-2019. Para isso, foram utilizados inventários para identificar as principais características das publicações. Os

resultados mostram: um número moderado de artigos (63), considerando a importância do tema em documentos norteadores; artigos (22%) que mencionam “pensamento crítico” sem citar referências de pensamento crítico; artigos (78%) que mencionam “pensamento crítico” e citam referências de pensamento crítico; e um conjunto de artigos (32%) que apresentam o pensamento crítico como foco principal, priorizando a discussão deste tema. Por outro lado, foi identificado um conjunto de artigos (43%) que teve maior enfoque nas propostas de ensino do que a investigação/discussão aprofundada do próprio pensamento crítico. É relevante a necessidade de mais publicações com foco principal no pensamento crítico no Ensino de Ciências e Educação Matemática, além de pesquisas em diferentes contextos, como a avaliação/desenvolvimento do pensamento crítico de alunos e professores.

Palavras-chave: Pensamento crítico; Ensino de ciências; Revisão sistemática da literatura.

Abstract

This research presents a systematic literature review of articles on critical thinking in Science Education and Mathematics Education. The objective is (1) to identify articles involving critical thinking in Science Education and Mathematics Education in international journals; and (2) to identify the main characteristics of these articles, in terms of: authors; years of publications; periodicals; authors' institutions; countries; citations; teaching levels; fields; the main references cited; and the number of mentions of the term critical thinking. The methodological procedures were performed according to Okoli’s 8 step guide (2015) for conducting a systemtic review and Bardin's Content Analysis (2011). The database used was the Education Resources Information Center (ERIC), from which 63 articles published in 2010-2019 were analyzed. For this, inventories were used to identify the main characteristics of the publications. The results show: a moderate number of articles (63), considering the importance the theme is given in guiding documents; articles (22%) that mention “critical thinking” without citing critical thinking references; articles (78%) that mention “critical thinking” and cite critical thinking references; and a set of articles (32%) that present critical thinking as its main focus, prioritizing the discussion of this theme. In contrast, a set of articles (43%) focused more on proposed teaching approaches than the in-depth investigation/discussion of critical thinking itself. The need for more publications with the main focus on critical thinking in Science Education and Mathematics Education is relevant, as well as research in different contexts such as the evaluation/development of students' and teachers' critical thinking.

Keywords: Critical thinking; Science education; Systematic literature review.

Resumen

Esta investigación presenta una revisión sistemática de la literatura de artículos sobre pensamiento crítico en la educación científica y la educación matemática. El objetivo es (1) identificar artículos que involucren el pensamiento crítico en Educación en Ciencias y Educación en Matemáticas en revistas internacionales; y (2) identificar las características principales de estos artículos, en términos de: autores; años de publicaciones; publicaciones periódicas instituciones de autores; países; citas niveles de enseñanza; campos; las principales referencias citadas; y la cantidad de menciones del término pensamiento crítico. Los procedimientos metodológicos se realizaron de acuerdo con la guía de 8 pasos de Okoli (2015) para realizar una revisión sistemática y el Análisis de contenido de Bardin (2011). La base de datos utilizada fue el Centro de Información de Recursos Educativos (ERIC), del cual se analizaron 63 artículos publicados en 2010-2019. Para esto, se utilizaron inventarios para identificar las principales características de las publicaciones. Los resultados muestran: un número moderado de artículos (63), considerando la importancia que se le da al tema en los documentos de orientación; artículos (22%) que mencionan "pensamiento crítico" sin citar referencias de pensamiento crítico; artículos (78%) que mencionan "pensamiento crítico" y citan referencias de pensamiento crítico; y un conjunto de artículos (32%) que presentan el pensamiento crítico como su enfoque principal, priorizando la discusión de este tema. En contraste, un conjunto de artículos (43%) se centró más en los enfoques de enseñanza propuestos que en la investigación / discusión en profundidad del pensamiento crítico en sí. La necesidad de más publicaciones con el enfoque principal en el pensamiento crítico en la Educación en Ciencias y la Educación en Matemáticas es relevante, así como la investigación en diferentes contextos, como la evaluación / desarrollo del pensamiento crítico de estudiantes y maestros.

Palabras clave: Pensamiento crítico; Educación científica; Revisión sistemática de literatura.

1. Introduction

In the international context, several documents point out the relevance of Science Education for the development of the critical thinking of citizens as a way of actively inserting them into personal and professional environments (Tenreiro-Vieira & Vieira, 2013). International reports and documents such as Science Education Now: A Renewed Pedagogy for the Future of Europe (ROCARD et al., 2007); National Science Education Standards (NRC, 1996); and Project Beyond 2000: Science Education for the Future (Reiss, Millar &

Osbourne, 1998) recognize that science education and its curriculum need to build a school that draws students' attention to the dimension of scientific knowledge and thus provides incentive to critical, logical and creative thinking.

Barrington, Wright & Casner-Lotto (2006) indicate the need to think about education as a space to prepare young people for the work environment and also highlight skills for this, such as critical thinking. Although critical thinking is developed over the years, it is up to the school to contribute in part of this process. Thus, the school environment together with teaching needs to be articulated to promote skills that awaken students' critical thinking, making them understand the relationship between science, technology and the environment they live in (Souza & Vieira, 2019).

Although the topic is relevant and mentioned in several guiding documents, there is a scarcity of bibliographic reviews referencing investigations in the area of Science Education and Mathematics Education (NRC, 1996; Reiss, Millar & Osbourne, 1998; Rocard et al., 2007), that discuss critical thinking in depth. Therefore, this systematic literature review seeks to contribute in identifying the main characteristics of the articles that address critical thinking and the contexts in which critical thinking is studied. Knowing the panorama of research that investigates critical thinking in Science Education and Mathematics Education can guide future research on this topic, highlighting its trends and possible gaps in the existing literature.

Thus, this research presents results of a systematic literature review over the last decade (2010-2019) of critical thinking in the field of Science Education and Mathematics Education. The main objectives are:

(1) To identify articles involving critical thinking in Science Education and Mathematics Education in international journals;

(2) To identify the main characteristics of these articles, in terms of: authors; years of publications; periodicals; authors' institutions; countries; citations; teaching levels; fields; the main references cited; and the number of mentions of the term critical thinking.

The questions that guided this research were:

(1) What has been published, in the international context, about critical thinking in Science Education and Mathematics Education?

(2) What are the main characteristics of these articles, in terms of: authors; years of publications; periodicals; authors' institutions; countries; citations; teaching levels; fields; the main references cited; and the number of mentions of the term critical thinking.

2. Theoretical Foundation

Critical thinking promotes the autonomy of society in terms of knowledge in view of the speed with which technology has been advancing over time. It brings the capacity of the citizen to become actively participative through scientific modernity (Tenreiro-Vieira & Vieira, 2013). However, critical thinking doesn't only make up the attribute position for the intellectual dimension, since it has a pluralist character, that is, it can be used to broaden and deepen social, psychological, philosophical and ethical perspectives (Amorim & Silva, 2014).

According to Ennis (1985, p. 45) critical thinking is a form of "reflective and reasonable thinking that is focused on deciding what to believe or do", containing two components: one more cognitive – called capacities and the other more affective, called dispositions. Amorim & Silva (2014) also report that different approaches and definitions can be found with regard to the notion of critical thinking.

Weddle (1984), who wrote a critical review of McPeck's work warns that critical thinking must be used uniformly, giving coherence to the description and complements that critical thinking has a dependency in the field that addresses it, this means that, for each dimension, arts, ethics, science, among others, we necessarily depend on getting to know the context in depth to the point of being able to draw conclusions about the subject. According to Ennis (1985), although the conceptions of critical thinking are fragile in people's minds, it is possible to state that: "it is a practical activity because deciding what to believe or do is a practical activity" (p. 45) and he adds that this ability involves several skills such as the formulation of hypotheses, questions, alternatives and plans for experiments.

Nevertheless, the expression 'critical thinking' is manifested in different ways and leads to multiple conceptualizations (Tenreiro-Vieira & Vieira, 2013; Amorim & Silva, 2014). Thus, Amorim & Silva (2014) emphasize the need for a more targeted denomination about the term in question and argue that "such clarification of the concept(s) is necessary to deal with other issues such as, in particular, outlining guidelines for teacher training and for the teaching and learning of science and mathematics" (p. 167, our translation).

McPeck (1981) creates an association between the term critical thinking and reflective skepticism, in order to give coherence to the term and standardize it. Tenreiro-Vieira & Vieira (2013) bring the perspective of McPeck and emphasize that: the use of reflective skepticism aims to establish appropriate reasons due to epistemological norms. In McPeck's view, therefore, a normative dimension of the area of knowledge in question stands out as defining critical thinking. As such, critical thinking necessarily varies from domain to domain and

cannot be seen as a set of general capabilities transferable to any context (p. 176, our translation).

For Lipman (1991), critical thinking is responsible and skilled thinking which facilitates good judgments since it is based on criteria, it is self-correcting and also sensitive to the context. For the author, the criteria are reasons, which provide support for citizens to have credibility and validity in their considerations or opinions. Moore & Parker (2012) claim that human beings think critically whenever they are guided by the criteria of evidence and logic.

Tenreiro-Vieira & Vieira (2013) complement that the critical thinker values others who have this ability and conclude: "a critical thinker must not only be able to assess the strength of the reasons to act in a certain direction based on principles, but also be willing to act in that way "(p. 177, our translation).

Barrington, Wright & Casner-Lotto (2006, p. 16) point out that critical thinking is part of the skills that should be explored by students of various age groups, and describe it as the student's ability to "exercise sound reasoning and analytical thinking; use knowledge, facts, and data to solve workplace problems; apply math and science concepts to problem solving".

Siegel (2003) presents objectives outlined for critical thinking at school, since training with this proposal is capable of providing autonomy in the way of reflective thinking, preparing them for adult life and offering intellectual resources for solving problems within the work environment and daily life. In addition, critical thinking is indispensable in Science Education and for related disciplines such as Biology, Physics, Mathematics and Chemistry.

For critical thinking to be incorporated at the various levels of education, it is essential that teachers have this engagement. In this way, the training of teachers and the provision of didactic resources for them is necessary, since many difficulties are encountered in the school environment, difficulties that range from low knowledge about the subject to the students' lack of commitment (Ennis, 1985; Vieira & Tenrero-Vieira, 2014).

The teacher immersed in this approach is able to inspire his students in order to encourage them to think about their actions, problems and results in the classroom in a reflective manner, looking for strategies that instigate students' thinking, challenging them in order to involve them in tracking the attitudes and decisions taken. These are some of the proposals of Swartz & McGuiness (2014) which can help the teacher to guide his/her didactics based on critical thinking.

Cultivating the adoption of strategies that encourage the development of critical thinking and creating the habit of metacognition is fundamental, considering the challenges

and performance of future professionals in the job market and, consequently, contributing to social well-being (Barrington, Wright & Casner- Lotto, 2006). In this way, Lipman (1991) describes critical thinking as a judgment based on criteria among which the capacities of "investigation, reasoning, organization and transfer of information" are linked (Tenreiro-Vieira & Vieira, 2013, p. 178, our translation).

In the studies of Halpern (2003) & Siegel (2003), these authors show that although critical thinking can be defined by different perspectives and in multiple areas of knowledge, the term accommodates particularities, characteristics and content common to each other, in order to allow that its definition can be understood as normative, configuring critical thinking as an educational objective.

3. Methodology

According to Fink (2019) a systematic literature review is an orderly, explicit, comprehensive and reproducible method for identifying, evaluating and synthesizing the existing body of completed and registered works produced by researchers and scholars in a given area. Vom Brocke et al. (2009) also discuss the importance of transparency in the process of exclusion and inclusion of sources to ensure credibility and allow other researchers the possibility to assess the completeness of the review and use the results of the review in their research.

Okoli (2015) presents a guide for the development of a systematic bibliographic review and describes, in detail, eight steps to ensure a rigorous bibliographic review that comprehensively summarizes and discusses the existing literature.

Each step is described below: (1) Identify the purpose - The first step requires that the reviewers clearly identify the purpose of the review and its goals. This step is necessary for the review to be transparent to readers; (2) Draft protocol and train the team - For a review that employs more than one reviewer, these need to be clear and agree on the procedure that will be followed. This requires a written and detailed protocol for all the reviewers to have consistency in conducting the review; (3) Apply practical screen - This step requires reviewers to be transparent about which studies they considered and eliminated for the review. (4) Search for literature - The 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 information

from each study; (6) Appraise quality - At this point, reviewers need to explain the criteria that were used to exclude documents. Researchers must classify all works included, according to the research methodologies or other criteria of their choice; (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 – This final step of the review consists of the reporting, in sufficient detail, of the results for other researchers to be able to independently reproduce the results if needed.

From the above, we describe the realization of the 8 stages, proposed by Okoli (2015), for this systematic review. In this research, step 1 consisted of elaborating the research objectives and problems, previously presented. Stage 2 consisted of preparing the protocol for the review with the aim of detailing the stages of the study.

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. Eric is an online digital library of education information and research. On this database, the expression "critical thinking" and "science education" was searched for in journal articles; of open access; and that had been published in the last ten years (2010-2019). This first search generated 119 results. We opted to search for articles published between the years 2010-1019 to identify the main characteristics of international publications involving critical thinking in the last decade. We also sought to find research trends involving critical thinking in Science and Mathematics Education, as well as the most cited references of critical thinking and the most researched areas. Thus, we sought to present a general view of what has been published in the last decade and highlight the existing gaps in literature and the most researched aspects.

In order to refine the search, the following exclusion criteria were implemented: exclusion of articles from other disciplinary areas (other than in the area of Science Education and Mathematics Education); unavailability of open access; conference articles or book chapters; and duplication of results. In order to check the disciplinary area, the title, the name of the journal and, when necessary, the abstract and keywords were read. Articles in the area of Education were considered only if they were published in Science Education or Mathematics Education journals. This procedure was used in order to maintain the representativeness of the analyzed publications. These exclusion criteria reduced the results to 63 articles, which constituted the *corpus* of this review.

Step 5 was the systematic extraction of information. For that, an Inventory for each analyzed article was filled out. This inventory was part of our "Protocol for review",

previously elaborated in step 2, from which relevant aspects to be analyzed in each article were defined, in order to characterize research involving critical thinking in Science Education and Mathematics Education. This process has been used by other studies, such as that of Sousa & Vieira (2019). The inventory model used can be seen in Table 1.

Table 1. The inventory model used.

Code	
APA Reference	
Authors' Institutions	
Journal	
Abstract	
Objective(s)	
Teaching levels	
Field	
Context of use of the term “critical thinking”	
Theoretical references of “critical thinking”	
Number of mentions of the term “critical thinking”	

Source: The authors.

In order to fill in the item– Context of use of the term “critical thinking”– the expression “critical thinking” was searched for in the Introduction, Theoretical Foundation and Conclusions; all the paragraphs that contained the term were read; and these fragments were transcribed into the inventory. To fill in the item– Theoretical references of "critical thinking"–, all the references presented in the previous item that were directly related to critical thinking were transcribed. The term “critical thinking” was also searched for in the References section of each article, from which the respective references were also transcribed. Finally, the last item of the inventory was filled according to the number of mentions of the term “critical thinking” located in the file.

In step 6, the completed inventories were read in order to assess their quality and analyze the consistency of the results with the previously established objectives. Stage 7 consisted of the analysis and synthesis of the inventories, from which this research seeks to

characterize the articles that addressed the theme critical thinking in Science Education and Mathematics Education from aspects presented by the authors. The analytical movements were performed according to Content Analysis by Bardin (2011), which is defined as a "set of communication analysis techniques" (p. 37, our translation), which presents as one of its main objectives the inference of relative knowledge conditions for the production of the message. According to Bardin (2011), Content Analysis is defined as a set of techniques for analyzing communications in order 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 is, in general terms, systematized in 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 and systematized in order to make the material operational (Bardin, 2011). In this research, the pre-analysis included brief reading, that is, the first contact with the articles; selection of articles; the formulation of hypotheses and objectives; and the preparation of the inventory, which served to determine the selections in the analysis material and the preparation of the material.

In the exploration of the material, the systematic administration of the decisions taken previously is carried out (Bardin, 2011). In this research, the exploration of the material consisted of an in-depth study, 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-A63 according to the order they were presented in the database. Bardin (2011) defines the categories resulting from this analytical and interpretative movement as rubrics or classes that bring together a group of elements under a generic title according to common characters among the elements.

During the third stage, inferences and interpretations are carried out regarding the planned objectives (Bardin, 2011). In this study, this step consisted of presenting results about the analysis of the articles according to their inventories and discussing the similarities and diversities found among the articles involving critical thinking in Science Education and Mathematics Education. Therefore, step 7 of Okoli's guide (2015) involved the three main phases of Bardin's Content Analysis (2011). Finally, step 8 consisted of writing this article and describing its stages in detail.

4. Results and Discussion

Table 2 shows the codification of the analyzed articles, in which the first column corresponds to the article reference and the second column to the code of the respective article. The discussions in this section were conducted using the article codes. In this section, the percentages presented in the discursive paragraphs have been rounded to maintain the standardization of the values without decimal places and to facilitate the discussions. The percentages shown in the tables contain one decimal place.

Table 2. Codification of the 63 articles reviewed in this research.

Article	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. *Acta Didactica Napocensia*, *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	A22

Learning: Design and Application of Convergent Science Experiments. *Universal Journal of Educational Research*, *3*(11), 937-942.	
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
Belanger, J. R. (2016). Learning in the Laboratory: How Group Assignments Affect Motivation and Performance. *Journal of Education and Learning*, *5*(1), 210-217.	A30
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.	A31
Sofroniou, A., & Poutos, K. (2016). Investigating the effectiveness of group work in mathematics. *Education Sciences*, *6*(3), 30.	A32
Kapucu, M. S. (2019). Students' Experiences of Design-Based Research in Science Applications Course: A Design and Development Research. *International Journal of Progressive Education*, *15*(5).	A33
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.	A34
Song, P. (2014). A handful of bacteria: A simple activity that engages students to think and	A35

write like a scientist. *Journal of Technology and Science Education*, *4*(1), 3-11.	
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.	A36
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.	A37
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.	A38
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.	A39
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.	A40
Richardson, N., Tooker, P. A., & Eshleman, A. (2014). Core sciences in first-year learning communities. *Learning Communities Research and Practice*, *2*(1), 4.	A41
Franco, Y. (2013). Building a Community of Inquirers in Your Classroom: Learning from Our Global Colleagues. *Electronic Journal of Science Education*, *17*(4), n4.	A42
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.	A43
Gautreau, B. T., & Binns, I. C. (2012). Investigating Student Attitudes and Achievements in an Environmental Place-Based Inquiry in Secondary Classrooms. *International Journal of Environmental and Science Education*, *7*(2), 167-195.	A44
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.	A45
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.	A46
Gold, A. U., Kirk, K., Morrison, D., Lynds, S., Sullivan, S. B., Grachev, A., & Persson, O. (2015). Arctic climate connections curriculum: A model for bringing authentic data into the classroom. *Journal of Geoscience Education*, *63*(3), 185-197.	A47
Rillero, P. (2016). Deep Conceptual Learning in Science and Mathematics: Perspectives of	A48

Teachers and Administrators. *Electronic Journal of Science Education*, *20*(2), 14-31.	
Zion, M., & Mendelovici, R. (2012). Moving from structured to open inquiry: Challenges and limits. *Science Education International*, *23*(4), 383-399.	A49
Viro, E., & Joutsenlahti, J. (2018). The StarT Project Competition from the Perspective of Mathematics and Academic Literacy. *Education Sciences*, *8*(2), 67.	A50
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.	A51
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.	A52
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.	A53
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.	A54
Bagán, H., Sayós, R., & García, J. F. (2015). Skill development in experimental courses. *Journal of Technology and Science Education*, *5*(3), 169-183.	A55
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.	A56
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.	A57
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.	A58
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.	A59
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.	A60
Fessakis, G., & Zoumpatianou, M. (2012). Wikipedia uses in learning design: A literature review. *Themes in Science and Technology Education*, *5*(1-2), 97-106.	A61
Ercan, O., & Bilen, K. (2014). Effect of web assisted education supported by six thinking	A62

hats on students' academic achievement in science and technology classes. *European Journal of Educational Research*, *3*(1), 9-23.	
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).	A63

Source: The authors.

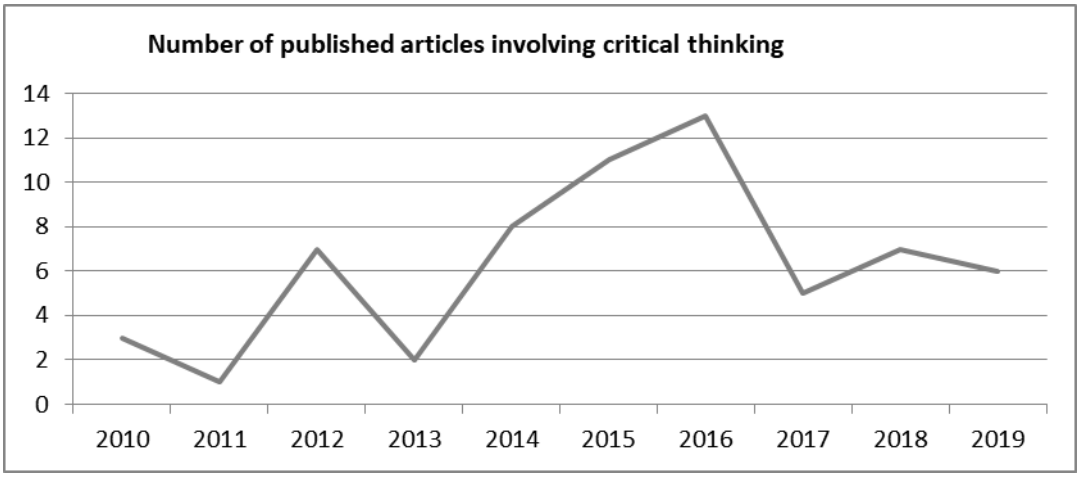
Regarding the authors who published articles involving critical thinking, there are no names that appear in more than 1 publication. In relation to the institutions that most published articles involving critical thinking, Gazi University, from Turkey can be highlighted, which contributed with 3 articles (5%) and then the University of Iowa, from the United States; the University of Georgia, United States; Masaryk University, Czech Republic; Kazan Federal University, Russia; and Marmara University, from Turkey, which contributed with 2 articles (3%) each.

17 articles (27%) were published by institutions in the United States, being the country with the largest number of publications. 16 articles (25%) were from institutions in Turkey; 3 articles (5%) from institutions in Indonesia; 3 articles (5%) from institutions in Russian; 2 articles (3%) from institutions in Portugal; 2 articles (3%) from institutions in Greece; 2 articles (3%) from institutions in Kazakhstan; 2 articles (3%) from institutions in the Czech Republic; and 2 articles (3%) from institutions in Israel. The following countries also appeared in 1 article each: Malaysia, Spain, Scotland, Jordan, South Korea, Nigeria, England, Thailand and Finland, corresponding to 2% each. Publications of collaborations between institutions in different countries were also identified, for example: 2 articles (3%) from an institution in the United States with one from Turkey; 1 article (2%) from an Indian institution with one from Singapore; 1 article (2%) from a United States institution with one from Taiwan; and 1 article (2%) from an institution in the United States with one from Australia.

Regarding the number of articles published and the period of publication, we present Figure 1. From Figure 1 it is possible to observe that 3 articles (5%) were published in 2010; 1 article (2%) in 2011; 7 articles (11%) in 2012; 2 articles (3%) in 2013; 8 articles (13%) in 2014; 11 articles (17%) in 2015; 13 articles (21%) in 2016; 5 articles (8%) in 2017; 7 articles (11%) in 2018; and 6 articles (10%) in 2019. The year 2016 can be highlighted with the largest number of publications involving the theme critical thinking, with 13 articles (21%). It i salso possible to note there was a greater number of publications since 2014, since 50 articles (79%) were published from 2014-2019 and only 13 articles (21%) between 2010-

2013.

Figure 1. Absolute frequency of articles published over the past 10 years.



Source: The authors.

Regarding the levels of education investigated, 13 groups were identified (Table 3). The educational levels presented were organized according to the three-stage system of the International Standardized Classification of Education (ISCED). The terms presented differently in the analyzed articles were converted to maintain the standard.

Table 3. Education levels of the articles.

Level	**Quantity of articles (percentage)**
Unspecified	8 (12,7%)
Elementary School (1st-5th grade)	4 (6,3%)
Middle School (6th-8th grade)	4 (6,3%)
High School (9th-12th grade)	8 (12,7%)
Middle School and High School	3 (4,8%)
High School and Undergraduate Education	2 (3,2%)
Undergraduate Education	12 (19%)
Pre-service Teacher Education	**16 (25,4%)**
In-Service Teacher Education	2 (3,2%)
Professional Education	1 (1,6%)
Graduate Education	1 (1,6%)
Preschool	1 (1,6%)
Preschool, Middle School, High School , College and Pre- Service and In- Service Teacher Education	1 (1,6%)

Source: The authors.

It is possible to observe that there was a greater number of articles involving Pre-Service Teacher Education (25%), Undergraduate Education (19%) and High School (13%). 8 articles (13%) did not specify the levels of education investigated, and many of the articles in this group were theoretical in nature. Furthermore 1 article (A53) allocated to the Elementary School group investigated students with disabilities; 1 article (A30) allocated to the Undergraduate Education group investigated military cadets; and 2 articles, (A22) and (A24), investigated students gifted in science, being allocated to the groups “Middle School and High School” and “High School”, respectively.

Regarding the knowledge fields, 18 groups were identified (Table 4).

Table 4. Knowledge fields of the articles.

Field	**Number of articles (percentage)**
Chemistry	6 (9,5%)
Science	**27 (42,9%)**
Not specified	4 (6,3%)
Biology	5 (7,9%)
Physics	3 (4,8%)
Agricultural Sciences	1 (1,6%)
Genetics	1 (1,6%)
Mathematics	3 (4,8%)
Science and Technology	1 (1,6%)
Physics, Chemistry and Biology	1 (1,6%)
Engineering	2 (3,2%)
Environmental Sciences	2 (3,2%)
Science and Engineering	1 (1,6%)
Applications of Science	1 (1,6%)
Life Safety	1 (1,6%)
Biotechnology	1 (1,6%)
Mathematics and Science	1 (1,6%)
Education	2 (3,2%)

Source: The authors.

Most of the articles belonged to the field of Science (43%). In relation to specific subjects, 6 Chemistry articles (9.5%); 5 Biology articles (8%); 3 Physics articles (5%); and 3 Mathematics articles (5%) were identified. Also, 4 articles (6%) did not specify the areas of knowledge investigated.

In relation to the journals in which the articles were published, the journals with the largest number of articles were: *International Journal of Environmental and Science Education*, with 13 articles (21%); *Science Education International*, with 7 articles (11%); *Educational Sciences*, with 6 articles (9,5%); and the *Journal of Technology and Science Education*, with 5 articles (8%). The *Electronic Journal of Science Education*; *European Journal of Science and Mathematics Education*; and the *Universal Journal of Educational Research* presented 3 articles (5%) each. The *Journal of Education and Learning*; *Eurasian Journal of Educational Research*; *Educational Sciences*: *Theory and Practice*; and *Bioscene*: *Journal of College Biology Teaching* presented 2 articles (3%) each.

The other journals presented only 1 article each: *Educational Policy Analysis and Strategic Research*; *Journal of Education and Training Studies*; *Acta Didactica Napocensia*; *International Journal of Instruction*; *Journal of Education and Practice*; *Journal of Agricultural Education*; *New Directions in the Teaching of Physical Sciences*; *Journal of Educational Sciences*; *International Journal of Progressive Education*; *Learning Communities Research and Practice*; *Journal of Geoscience Education*; *Journal of Science Education for Students with Disabilities*; *Themes in Science and Technology Education*; *European Journal of Educational Research*; *International Journal of Multicultural Education*.

Table 5 shows the articles from the *corpus* that were most cited on Google Scholar[1], as well as the research context in which the perspective of critical thinking was present in these articles. In column 1 are the codes of the most cited articles, in column 2 the number of citations, and in column 3 the context of critical thinking of the articles. We emphasize that the number of citations was sought on 21/03/2020.

Table 5. Contexts of critical thinking of the most cited articles.

Articles	**Number of citations**	**Context of critical thinking**
A49	153	The article provides science teachers with definitions of inquiry and its levels, relating them to real-world scientific processes. The article also presents a model implemented in the teaching of high school biology in Israel over the past twelve years, consisting of several components, each of which has proved to be independently important for research teaching by the relevant available literature. The article discusses the potential of inquiry to develop students' critical thinking, specifically that the highest level of inquiry, open inquiry, simulates and reflects the type of research and experimental work that is done by scientists and requires highorder thinking capabilities of students, such as questioning, designing an experimental array, critical and logical thinking and reflection.
A11	118	The article discusses that one of the obstacles of critical thinking in Science Education is the fact that teachers do not have a clear idea about its concept, due to the meaning attributed to critical thinking in different contexts rarely being explicit. The article seeks to clarify the concept of

[1] https://scholar.google.com/

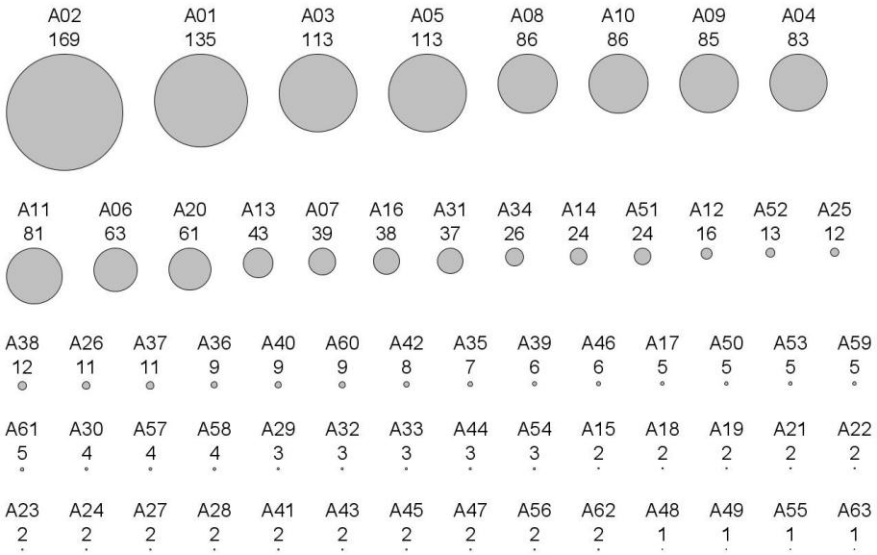
		critical thinking, presenting the perspectives of different authors and highlighting its relationship with other concepts, such as scientific literacy. The article also seeks to present and discuss a framework to promote students' critical thinking in science classrooms
A46	110	The article seeks to explore the effectiveness of an inquiry-based cellulase laboratory unit in promoting inquiry in undergraduate biotechnology students. According to the research results, the students' reports about their projects demonstrate that the proposed laboratory unit developed critical thinking, scientific process skills and skills to apply cellulase enzyme knowledge to industrial applications.
A58	99	The article seeks to determine the effect of diaries on self-regulatory strategies and the academic performance of pre-service science teachers. Regarding critical thinking, the article states that at the end of the study, no significant difference was found between the experimental group and the control group regarding the use of extrinsic motivation, belief control, self-efficacy, critical thinking, among others.
A63	61	The article seeks to share three examples of initial ventures by one of the authors, using science teaching in a culturally relevant way as a viable possibility to build the bridge between the distances between school education and the forms of knowledge and realities within homes and communities of culturally diverse students. The article comments on an author who sought to increase the interest of African American students in science and the number of African American scientists, by developing students' critical thinking skills, demonstrating the interdisciplinary nature of science and challenging the notion that science learning is boring and irrelevant to real life contexts.

Source: The authors.

It is possible to note a relationship between inquiry and the theme critical thinking, among the most cited articles, since 2 of these articles (A49 and A46) investigated these relationships. Also, some of the most cited articles presented the term critical thinking in representative sections of the text, such as in their abstracts, but their research objectives or questions did not contain the term. Of the most cited articles in Table 5, only A11 presented the term critical thinking in the objectives. In total, 20 articles (32%) presented the term critical thinking in their objectives (A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A13, A14, A16, A20, A25, A27, A32, A34, A52).

Regarding the amount of mentions to the term critical thinking in the articles, Figure 2 is presented, in which the 63 articles are represented by 63 circular nodes[2]. Each node contains a label with the code of the respective article and the number of mentions to the term critical thinking in the article. The diameters of the nodes are equivalent to the number of mentions to the term in each article, making it easier to view the articles that most mentioned the term critical thinking and the articles that least mentioned the term critical thinking.

Figure 2. Diagram of the number of mentions to the term critical thinking in the articles.



Source: The authors.

From the information expressed in Figure 2, it can be seen that the articles that most frequently mention the term critical thinking are: A02, A01, A03, A05, A08; A09, A04 and A11, with 169 to 81 mentions. Thus, it is noted that most of the articles presented few mentions to the term critical thinking, although they use the expression throughout the text. These articles remained in the corpus, as they contained the term critical thinking in representative sections such as the title, abstract or keywords.

In contrast, 20 articles (32%) discussed/investigated critical thinking in deeper levels, presenting the term in their research objectives (A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A13, A14, A16, A20, A25, A27, A32, A34, A52). These articles are mostly found in the first and second lines of Figure 2. In contrast, 27 articles (43%) that mention the

[2] Term used to designate graphic objects used to visually represent geometric information, an entity or any other types of data.

term critical thinking less than 5 times were also identified.

Regarding the references presented in the articles, 2 categories were identified, shown in Table 6.

Table 6. Critical thinking references presented in the reviewed articles.

Category	Description	Articles
R1	Articles that mention the term critical thinking without citing references which discuss this theme.	A15, A21, A22, A23, A27, A030, A32, A35, A41, A46, A048, A055, A58, A63
R2	Articles that mention the term critical thinking and cite references which discuss this theme.	A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A12, A13, A14, A16, A17, A18, A19, A20, A24, A25, A26, A28, A29, A31, A33, A34, A36, A37, A38, A39, A40, A42, A43, A44, A45, A47, A49, A50, A51, A52, A53, A54, A56, A57, A59, A60, A61, A62

Source: The authors.

14 articles (22%), were identified, that mention the term critical thinking without citing references which discuss this theme, so these articles were allocated to the R1 category. On the other hand, there were 49 articles (78%) that mention the term critical thinking and cite references which discuss this theme, so these articles were allocated to the R2 category. Table 7 presents the references most cited by the articles with regard to critical thinking.

Table 7. Most cited references.

Reference	Reference Code	Articles
Birgili (2015)	Ref 1	A01, A03
Facione (2013)	Ref 2	A01, A13
APA (1990)[3]	Ref 3	A02, A05
Ennis (1991)	**Ref 4**	A02, A04, A20

[3] American Philosophical Association.

Ernst & Monroe (2004)	Ref 5	A02, A05
Facione (1990)	**Ref 6**	A02, A04, A06, A09
Halpern (1998)	Ref 7	A02, A04
Kuhn (1999)	**Ref 8**	A02, A04, A31
Lipman (1991)	Ref 9	A02, A51
Moore & Parker (1998)	Ref 10	A02, A20
Ten Dam &Volman (2004)	Ref 11	A02, A11
Aizikovitsh-Udi & Amit (2011)	Ref 12	A03, A14
Alghafri & Bin Ismail (2014)	**Ref 13**	A03, A13, A14
Marzano et al. (1988)	Ref 14	A03, A09
Vieira, Tenreiro-Vieira & Martins (2011)	**Ref 15**	A03, A05, A09
Živković (2016)	Ref 16	A03, A06
Bakır (2015)	Ref 17	A04, A05
Lai (2011)	Ref 18	A04, A09
Walsh & Hardy (1999)	Ref 19	A04, A08
Facione, Facione & Giancarlo (1998)	Ref 20	A05, A10
Facione, Facione & Giancarlo (2000)	Ref 21	A05, A09
Gunn, Grigg & Pomahac (2008)[4]	Ref 22	A05, A11
Tümkaya & Aybek (2008)	Ref 23	A05, A10
Halpern (2000)	Ref 24	A07, A37
Beyer (1987)	Ref 25	A08, A20
Ennis (1996)	**Ref 26**	A08, A09, A11
Ennis & Millman (1985)	Ref 27	A08, A09
Norris (1985)	Ref 28	A08, A09
Bailin (2002)[5]	**Ref 29**	A10, A11, A52, A60
Paul (1993)	Ref 30	A10, A11
Schafersman (1991)	Ref 31	A10, A20
Shakirova (2006)	Ref 32	A34, A51

Source: The authors.

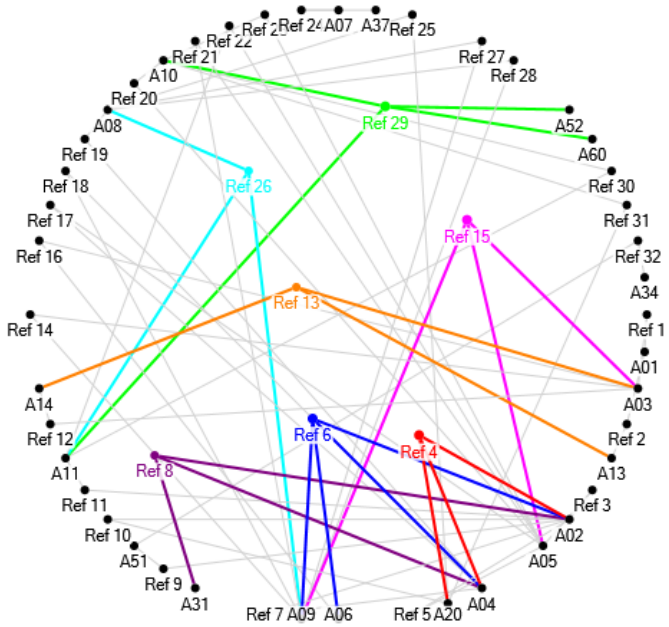
[4] The same work from 2007 was also considered.

[5] The same work from 2001 was also considered.

From Table 7 and considering only the 49 articles in category R2, that is, the articles that mention the term critical thinking and cite references which discuss critical thinking, we highlight the most cited references. There were a total of 32 references manifested more than once, in which 7 references stood out. Bailin (2002) and Facione (1990) were the most cited references, being present in 4 articles (8%) each. Ennis (1996); Vieira, Tenreiro-Vieira & Martins (2011); Alghafri & Bin Ismail (2014); Kuhn (1999); and Ernst & Monroe (2004) were cited by 3 articles (6%) each.

In Figure 3, the Microsoft Excel supplement, NodeXL, was used to map the list of the most cited references and the reviewed articles. These maps use loops and colors to emphasize authors or concepts that are interconnected. The references in the center of the figure, highlighted by colors, are the ones that were most cited, that is, mentioned in more than 3 or 4 articles. For example, Facione (1990) - Reference 6 - was mentioned in articles A02, A04, A06 and A09 and Bailin (2002) - Reference 29 - in articles A10, A11, A52 and A60. In addition to this relationship between authors and articles, it is possible to observe, from the map of relations constructed, the number of citations mentioned in the same article.

Figure 3. Relationship between the most cited references and the articles.



Source: The authors.

Thus, through Figure 3, the 32 most cited references and the 20 articles (A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A13, A14, A20, A31, A34 , A37, A51, A52, A60) that mention them are presented. It was possible to highlight the 7 most representative

references of this research mentioned in Table 7.

Of the 20 articles that present the most cited references in their research, 15 mention the 7 highlighted references. A02 (Ref 4, Ref 6 and Ref 8), A04 (Ref 4, Ref 6 and Ref 8) and A09 (Ref 6, Ref 15 and Ref 26) have 3 of the highlighted references in Figure 3. A03 (Ref 13 and Ref 15) and A11 (Ref 26 and Ref 29) have 2 of the highlighted references in Figure 3. The others; A05 (Ref 15), A06 (Ref 6), A08 (Ref 26), A10 (Ref 29), A13 (Ref 13), A14 (Ref 13), A20 (Ref 4), A31 (Ref 8), A52 (Ref 29) and A60 (Ref 29) have only 1 highlighted reference in Figure 3.

This figure also shows the crossings between the various articles that cite the same references. For example, even though article A05 presented a considerable amount of references (in total, 7), only one was mentioned by other researchers (Ref 15). The article A02, on the other hand, presented 11 references, of which 3 were also referenced by other researchers: Ref 4, Ref 6 and Ref 8. Also, the references cited by article A04 also are cited by A02.

5. Final Considerations

Given the results of this research, the research questions can be resumed: 1) What has been published, in the international context, about critical thinking in Science Education and Mathematics Education? 2) What are the main characteristics of these articles, in terms of: authors; years of publications; periodicals; authors' institutions; countries; citations; teaching levels; fields; the main references cited; and the number of mentions of the term critical thinking.

Thus, in relation to the first question, 63 articles were identified, a quantity considered to be modest in terms of critical thinking in Science Education and Mathematics Education. This despite its relevance in official documents guiding Basic Education and discussions about teaching aimed at the development of critical thinking.

Among the articles analyzed, all authors presented only one publication about critical thinking. The institution with the largest number of publications was Gazi University, in Turkey, which contributed with 3 articles (5%) and then the University of Iowa, in the United States; the University of Georgia, United States; Masaryk University, Czech Republic; Kazan Federal University, Russia; and Marmara University, from Turkey, which appeared in 2 articles (3%) each. The majority of the articles were from the United States and Turky, of which 17 articles (27%) were from institutions in the United States, followed by 16 articles

(25%) from institutions in Turkey. 2016 was the year with the largest number of publications involving critical thinking, with 13 articles (21%). Also, there was a greater number of publications since 2014, since 50 articles (79%) were published from 2014-2019. Among the levels of education investigated, 13 groups were identified, most of which belonged to Pre-Service Teacher Education, with 16 articles (25%), followed by 12 articles (19%) from Undergraduate Education and 8 articles (13%) from High School. Regarding the knowledge fields, 18 groups were identified, of which the majority (43%) belonged to the area of Science. In relation to specific fields, 6 Chemistry articles (10%); 5 Biology articles (8%); 3 Physics articles (5%); and 3 Mathematics articles (5%) were identified.

The journal with the largest number of publications involving critical thinking was the *International Journal of Environmental and Science Education*, with 13 articles (21%), followed by *Science Education International*, with 7 articles (11%).

Regarding the references presented by the articles, 2 categories emerged, R1 and R2. 22% of the articles mentioned the term critical thinking without citing references which discuss this theme (R1). 78% of the articles mentioned the term critical thinking and cited references which discuss this theme (R2). The number of articles allocated to the R2 category can be considered high and we note the theoretical foundation of these articles, which contained different definitions for the term critical thinking and presented different authors' perspectives on the theme. Among the articles analyzed, the most cited theoretical references were Bailin (2002, 2001) (8%) and Facione (1990) (8%).

The most cited articles, in decreasing order, were: A49, A11, A46, A58, and A63 with 153, 118, 110, 99, and 61 citations, respectively. In total, 20 articles (32%) were identified that presented the term critical thinking in their research objectives or questions (A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A13, A14, A16, A20, A25, A27, A32, A34, A52). Based on this fact and the critical thinking contexts of these articles, we consider these articles to have a greater focus on the investigation/discussion of critical thinkin. In addition, we noticed a relationship between these articles and those with the highest number of mentions of the term critical thinking, since those with the highest number of mentions were also part of this group. In this sense, articles A02, A01, 03, A05, A08 were the ones with the highest number of mentions; presenting 169, 135, 113, 113, and 86 mentions respectively.

27 articles (43%) that mentioned the term critical thinking less than 5 times were identified. Many of these articles discussed approaches that promote critical thinking, or highlighted the importance of critical thinking in Science Education and Mathematics Education, as well as in guiding documents. Thus, their objectives were more focused on the

proposed approaches than the investigation/discussion of critical thinking itself. We consider the need for more publications with the main focus on critical thinking in different contexts relevant, such as the development of critical thinking of students and teachers, the proposal of approaches aimed at critical thinking, and the evaluation of students' and teachers' critical thinking. These gaps found in existing literature corroborate the discussions of authors such as Sousa and Vieira (2019, p. 27), who claim that "significant evidence of the development of critical thinking and the construction of scientific knowledge relevant to students are perceived when strategies and activities didactics are explicitly designed to develop students' critical thinking".

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