Environmental education and climate change: bibliometric analysis

Educação ambiental e mudanças climáticas: uma análise bibliométrica

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ABSTRACT: Environmental Education (EE) can help coping with the climate environmental crisis through the development of strategies focused on mitigating, and adapting to, the causes and effects of Climate Change (CC). Thus, the aim of the current study is to use a bibliometric approach to analyze scientific production representativeness in studies about EE and CC. Bibliometric analysis applied to the number of publications on this topic was carried out by taking into consideration the following aspects: journal, publication year, language, institution and classification of the most cited articles. VOSviewer software was used to map the results of the analyzed studies, based on the co-occurrence of keywords and cooperation networks between countries, institutions, as well as on articles' co-citation. There was annual growth in the number of studies published in the last 10 years; 25.6% of them were published in Qualis A1 Environmental Sciences journals, according to Capes. English was the prevalent language of the analyzed publications; it accounted for approximately 98% of the published studies. The United States accounted for most of the published studies (34.5%); it was followed by European countries (27.8%). However, there was increase in the number of studies conducted in China, South Africa, India and Brazil. Therefore, although there was evident growth in the number of research about EE and CC, it is important expanding institutional cooperation to help developing inter-institutional and multinational research.

Keywords: Brazil; education; climate education; VOSviewer.

RESUMO: A Educação Ambiental (EA) tem potencial para contribuir no enfrentamento da crise ambiental climática, com a criação de estratégias de mitigação e adaptação das causas e efeitos das Mudanças Climáticas (MC).

Nesse sentido, objetivou-se analisar a representatividade da produção científica, sob o enfoque bibliométrico, em estudos que envolvam EA e MC. Para tanto, realizou-se análises bibliométricas sobre a quantidade de publicações por periódico, por ano, por idioma, por instituição e classificação dos artigos mais citados. Também, efetuou-se mapeamentos dos resultados encontrados por meio do software VOSviewer sobre: coocorrência de palavras-chave e redes de cooperação entre países, instituições e cocitação de artigos. Observou-se crescimento anual de publicações nos últimos 10 anos, sendo 25,6% do total de publicações feitas em periódicos Qualis A1 em Ciências Ambientais. O idioma predominante foi o inglês em quase 98% dos trabalhos. A concentração das produções ficou com os Estados Unidos (34,5%) e países da Europa (27,8%), no entanto, havendo aumento de estudos e ganhando destaque países como China, África do Sul, Índia e Brasil. Assim sendo, fica evidente o crescimento de estudos sobre EA e MC, mas é importante ampliar as cooperações institucionais, a fim de desenvolver pesquisas interinstitucionais e multinacionais.

Palavras-chave: Brasil; educação; educação climática; *VOSviewer*.

1. Introduction

Climate Change (CC) phenomenon intensification has posed challenges to both society and the environment. Among them, one finds rising sea levels and extreme events, such as biodiversity loss, migratory flows and changes in rainfall rates, which can have natural and anthropogenic causes, and mainly affect the most socioeconomically vulnerable populations (Di Giulio *et al.*, 2019; Souza, 2020; Teixeira *et al.*, 2020).

CC is acknowledged as global public issue faced by humankind, although it equally affects non-human life. Thus, it requires political, economic and cultural responses and solutions from governments and international organizations, social movements of all types, companies, research centers, media and educators, as well as demands the participation, change and adaptation of all individuals (Lima & Layrargues, 2014). Accordingly, education can work as mechanism to change society by promoting actions aimed at mitigating CC. It happens because schools are spaces for reflection, where students have the opportunity to engage in citizenship models, with emphasis on collective decision-making processes (Jickling, 2013).

According to the National Curriculum Guidelines for Environmental Education (DCNEA - Diretrizes Curriculares Nacionais para a Educação Ambiental), discipline matrix planning and teaching management should help establishing associations between CC and the current production, consumption and social organization model in order to help preventing environmental disasters and protecting communities, based on knowledge and sustainability values, on different manifestations of life, as well as on established principles and goals (Brasil, 2012).

Thus, Environmental Education (EE) can contribute to develop educational practices focused on addressing CC impacts and on better understanding the meaning of factors capable of affecting the environment. In addition, it can help society to achieve sustainability and transform citizens by making them reflect about, and become aware of, their relevance in society and, consequently, to spread the idea of environmental conservation to help reducing impacts on the environment and enabling better quality of life for both the present and future generations (Flores & Amigón, 2018; Silva, 2019).

Given the importance of conducting research on CC, mainly in the educational context, EE stands out for favoring the replacement of individual beha-

viors by collective actions. It is so, because it helps building social, political, cultural and environmental values for climate education, as well as improving knowledge, skills and attitudes towards environmental conservation, sustainability and quality of life. Therefore, the aim of the current study was to use the bibliometric approach to analyze scientific production representativeness in studies about EE and CC.

Bibliometric plays primordial role in the analysis of scientific production behaviors and helps increasing the visibility of new information and knowledge sources, based on the assessment of patents, theses, dissertations, among other scientific research publications (Pimenta *et al.*, 2017). Bibliometric studies enable guiding investigations about a given topic and help finding scientific production indicators by identifying aspects, such as temporality, origin of studies, investigated topics and adopted methodologies (Galvão *et al.*, 2015).

2. Global climate change: the educational perspective

Association between education and CC plays relevant role in the current environmental context. Education plays key part in raising awareness and in promoting behavioral changes in individuals. In addition, it increases community's CC mitigation and adaptation ability, as well as enables citizens to make well-informed decisions (UNESCO, 2017). Thus, the ultimate goal of CC education is to encourage "climate action", i.e., practices adopted by individuals to help reducing anthropic impacts on global climate, in order to reduce CC effects on the global population and on the environment (Moser, 2016; Henderson *et al.*, 2017; Monroe *et al.*, 2017).

In light of the foregoing, climate action adaptation to specific contexts promotes messages capable of echoing on local citizens, with emphasis on increasing the climate literacy of both teachers and basic education students. It must be done in order to provide different generations with knowledge capable of contributing to individuals' attitude towards climate-related topics (USGCRP, 2009; Deng *et al.*, 2017). It is so, because climate literacy is a challenging topic in formal educational contexts, worldwide (Blum *et al.*, 2013; Monroe *et al.*, 2017).

Several studies have emphasized the complexity of climate literacy and persistent misconceptions about CC (Niebert & Gropengiesser, 2013; Busch *et al.*, 2018). In addition to issues associated with the complex nature of CC, educators working with diverse audiences - from young students in schools to adult individuals in communities - report additional barriers to deliver effective climate education (Monroe *et al.*, 2019). This issue may be associated with the current teaching methods applied to CC, i.e., a geographic process focusing on individual actions (Waldron *et al.*, 2016).

According to Arya & Maul (2016), evidence--based discussions held in classrooms encourage students' engagement in scientific data about CC. Thus, previous ideological concepts can open room for contextualized ideas when students have access to information and are encouraged to talk about a given topic. In addition, student-to-student and teacher-to-student interactions, based on dialogue, provide students with opportunities to use their decision-making and argumentative skills to promote

greenhouse gas reductions, social patterns and lifestyles (Byrne *et al.*, 2014; Karpudewan *et al.*, 2015).

Therefore, if the aim of a given experience in CC education is to encourage action, Busch et al. (2019) have suggested that educators must take into consideration individual attitudes and social standards to enable an appropriate CC approach at school, in order to turn the classroom into a discussion and knowledge construction environment. It is relevant implementing teaching strategies, developing appropriate resources to each context and training teachers if one bears in mind that basic education students still have a hard time understanding the natural causes of CC, the greenhouse effect and the ozone layer, as well as the nature of greenhouse gases and radiation types, differences between climate and air pollution (Lambert *et al.*, 2012; Dawson, 2015).

From the climate education perspective, EE plays important role in classroom, since it enables students to better understand individual and collective accountabilities for environmental issues, as well as the transforming role played by them in society (Silva *et al.*, 2020). EE shaped to integrate climate knowledge at different education levels enables sharing updated information on a given subject, as well as enables the joint search for solutions to environmental issues (Mesquita *et al.*, 2019).

Therefore, it is essential emphasizing that the theoretical basis that has been built to climate education shares and strengthens the idea of legitimizing changing terminologies' proliferation at the whim of events and trending topics, such as education focused on biodiversity, CC and even on sustainable development (Saito, 2017). According to Benac & Freire (2018, p. 68), "EE educational processes must be committed to ethics in new possibilities that may emerge in dialogic spaces at the time to deal with contemporary environmental issues."

Finally, it is necessary thinking about new ways of dealing with this issue through different approaches, in order to face CC from the EE perspective. It can be done by problematizing the current economic-technological-scientific discourse that naturalizes socio-environmental injustices associated with this topic. It must be done by encouraging both individuals and the community to take a stand about this discourse, as well as by developing public policy actions focused on providing principles and guidelines to qualify, strengthen and gear up the school community, and to make public and business managers aware of global climate change complexity and to create substantial conditions to find different ethical, social, political, individual and collective transformation paths (Tamaio, 2013; Benac & Freire, 2018).

3. Materials and methods

Bibliometrics refers to using statistical and mathematical methods to describe and measure written communication (in this specific case, articles) about a given discipline or topic (Chueke & Amatucci, 2015; Silva & Niyama, 2019). According to Quevedo-Silva *et al.* (2016), bibliometric studies are featured as descriptive research, since they aim at presenting the main authors, journals and titles identified in the analyzed field (topics).

According to Wolfram (2016), bibliometrics started to be used as methodology to help assessing and better understanding the performance of academic scientific production activities, based on using data about the investigated period in order to extract

all necessary information. It is worth emphasizing the use of statistical and mathematical methods capable of making the scientific productivity assessment process more objective.

Search in the *Web of Science* database was herein conducted on August 7, 2020, based on using the following descriptors: ("Environmental Education" OR "Climate Education" OR "*Education*") AND ("Climate Change") - 4,083 "All document types" publications have emerged. On the other hand, 3,214 studies were observed when only document type "article" was specified. It is essential pointing out that the use of asterisk (*) in the descriptors aimed at including expressions goes beyond the written word, such as: education policy, education system, among others.

The search was refined based on using the following *Web of Science's* categories for better targeting purposes: Environmental Sciences, Environmental Studies, Environmental Education Research, Green Sustainable Science Technology, Ecology and Education Scientific Disciplines - 1,850 studies have emerged from this search and they formed the sample used as basis for the analysis. All articles generated in the search process were taken into consideration, without temporal frame.

The following indicators were used in the first part of the bibliometric analysis, based on Silva *et al.* (2020): journals holding the largest number of articles; the most cited articles; number of articles per author; number of articles per year and foreign language; number of articles per institution; article's co-citation network by taking into consideration articles' references; cooperation network between countries and institutions; keywords' co-occurrence among publications.

The number of studies associated with the first 5 indicators was directly surveyed at the *Web*

of Science database search site, which enables such analyses.

Next, search results were mapped in VOSviewer software to elaborate the last three listed indicators. This software enables building and visualizing bibliometric network maps, based on the occurrence frequency of a particular term in publications' titles and abstracts. The size of the circles (terms) in their output is an indication of each term's occurrence frequency, whereas the distance between two circles is inversely proportional to the association among these terms; in addition, different colors represent different groups of topics (Zyoud, 2018).

4. Results and discussion

This section presents quantitative data such as journals, citations, authors, publications per year, language and institutions, as well as the mapping process (based on using VOSviewer software) applied to the co-citation network, to cooperation between countries and institutions, and to keywords' co-occurrence.

4.1. Quantitative analyses of publications

The analyzed sample comprised 1,850 articles that were distributed among the following research fields in the *Web of Science* database: Environmental Sciences Ecology (1,349 articles; 73% of the sample); Environmental Education Research (564 titles; 30.4% of the sample); Science Technology and Other Topics (336 titles; 18.2% of the sample); Meteorology and Atmospheric Sciences (151 titles; 8.2% of the sample); Engineering (120 titles; 6.5% of the sample); Public, Environmental and Occupa-

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tional Health (82 titles; 4.4% of the sample); among other less-representative fields.

Most publications regarded the Environmental Sciences and Education fields, which comprise public policies, ecology, technology and meteorology. It is important clarifying that the same article can be classified in more than one field; therefore, articles belonging to Environmental Sciences and Education field can also emerge in the Environmental Public Health or Engineering field. In addition, there were articles observed in different fields, such as communication, psychology and public administration.

The following results were observed based on the number of publications per journal (Table 1):

Sustainability (131 articles; 7.1% of the sample); *Environmental Education Research* (4.5% of the sample); *Journal of Cleaner Production* (3.8% of the sample); *Climate Change* (2.9% of the sample); *International Journal of Environmental Research and Public Health* (2.3% of the sample); *Global Environmental Change: Human and Policy Dimensions* (1.8% of the sample); among other less-representative journals. Although no Brazilian journal stood out among the ones mostly publishing in this field, 26.8% (11 titles) of Brazilian articles were published in the aforementioned journals.

TABLE 1 – Journals accounting for the largest number of publications about environmental education and climate change in the *Web of Science* database.

	Journals	N. of articles	Mean (%)
1st	*Sustainability*	131	7.08
2nd	*Environmental Education Research*	83	4.49
3rd	*Journal of Cleaner Production*	71	3.84
4th	*Climatic Change*	53	2.87
5th	*International Journal of Environmental Research and Public Health*	43	2.32
6th	*Global Environmental Change Human and Policy Dimensions*	34	1.84
7th	*International Journal of Climate Change Strategies and Management*	30	1.62
8th	*International Journal of Science Education/ International Journal of Sustainability in Higher Education*	29	1.57
9th	*Land Use Policy*	26	1.41
10th	*Regional Environmental Change/ Science of The Total Environment*	24	1.30
11th	*Weather Climate and Society*	23	1.24
12th	*Environmental Science Policy*	22	1.19
13th	*Environment Development and Sustainability/ International Research in Geographical and Environmental Education/ Journal of Environmental Management*	21	1.14
14th	*Ecology and Society/ Energy Policy/ Journal of Environmental Education*	19	1.03
15th	*Environmental Science and Pollution Research*	17	0.92
16th	*Environmental Management/ Mitigation and Adaptation Strategies For Global Change*	16	0.87
17th	*Environmental Communication a Journal of Nature and Culture/ Environmental Research*	15	0.81

SOURCE: *Web of Science*, adapted by the authors, 2020.

Based on enquiry conducted at "Sucupira-Qualis Periódicos da CAPES", one can state that, among journals with the largest number of publications in the investigated field, 13 are classified as Qualis A1 in the Environmental Sciences field, - they accounted for 25.6% of publications -, whereas the *International Journal of Science Education*, which comprised 29 articles (1.6% of the total sample), is classified as Qualis A1 in the Education field. This finding has evidenced that Education journals have been publishing a small number of studies about EE and CC.

Table 2 lists the titles of the first 20 most cited articles, along with their respective authors' name, publication year, number of citations and mean number of citations per year. Although some articles were recently published, they are already cited and account for high annual mean number of citations.

The article by Kollmuss & Agyeman (2002) was the most cited one (88 citations); however, based on its annual mean number of citations (4.63), it is the fifth most relevant study. Thus, the study by Field & Barros (2014), which was the fourth most cited article (61 citations), rose to 1st position in the "relevance" ranking with annual mean number of citations of 8.71. On the other hand, the 13th most cited article (47 citations), which was written by Lee *et al.* (2015), rose to the 2nd position in the "relevance" ranking, based on its annual mean number of citations (7.83).

Thus, it is possible seeing that publications have been addressing topics associated with socio-environmental vulnerability, mitigation measures, adaptation to CC and individuals' perceptions about this topic. According to Lee *et al.* (2015), the perceptions of individuals interviewed in several countries have emphasized the need of developing customized climate communication strategies for each country. Results have suggested that improving basic education, climate literacy and public understanding about CC's local dimensions is essential to enable public engagement in, and support to, climate actions.

On the other hand, Kollmuss & Agyeman (2002) have suggested a model to incorporate demographic, economic, social, cultural and socio-emotional factors (motivation, awareness, values, attitudes, emotions, responsibilities, among others) capable of influencing pro-environmental behavior. Thus, the aforementioned model helps enlightening this complex scenario by filing the gaps between individuals' environmental knowledge and environmental awareness. Accordingly, the study by Field & Barros (2014) addressed impacts, adaptation measures and vulnerability factors, by covering global and local aspects.

TABLE 2 – Most cited articles about environmental education and climate change in the Web of Science database.

Title	Authors	Year	Citations			
			Total		Mean*	
Climate Change 2014-Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects: Volume 1, Global and Sectoral Aspects: Working Group II Contribution to the IPCC Fifth Assessment Report.	FIELD, Christopher B.; BARROS, Vicente R.	2014	61	4th	8.71	1st
The politicization of climate change and polarization in the American public's views of global warming, 2001–2010.	MCCRIGHT, Aaron M.; DUNLAP, Riley E.	2011	68	2nd	6.80	4th

Title	Authors	Year				
Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?	KOLLMUSS, Anja; AGYEMAN, Julian	2002	88	1st	4.63	5th
The polarizing impact of science literacy and numeracy on perceived climate change risks.	KAHAN, Dan M *et al.*	2012	63	3rd	7.00	3rd
Predictors of public climate change awareness and risk perception around the world.	LEE, Tien Ming *et al.*	2015	47	10th	7.83	2nd
Barriers perceived to engaging with climate change among the UK public and their policy implications	LORENZONI, Irene; NICHOLSON-COLE, Sophie; WHITMARSH, Lorraine	2007	59	5th	4.21	7th
Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia.	DERESSA, TemesgenTadesse *et al.*	2009	55	6th	4.58	6th
Adaptation, adaptive capacity and vulnerability.	SMIT, Barry; WANDEL, Johanna.	2006	53	7th	3.53	11th
Education, politics and opinions about climate change evidence for interaction effects.	HAMILTON, Lawrence C.	2011	41	13th	4.10	8th
Climate change risk perception and policy preferences: The role of affect, imagery, and values.	LEISEROWITZ, Anthony.	2006	49	9th	3.27	13th
Climate Change 2007 Synthesis Report.	PACHAURI, R.K; REISINGER, A.	2007	47	10th	3.36	12th
Cool dudes: The denial of climate change among conservative white males in the United States.	MCCRIGHT, Aaron M.; DUNLAP, Riley E.	2011	38	15th	3.80	9th
The effects of gender on climate change knowledge and concern in the American public.	MCCRIGHT, Aaron M.	2010	39	14th	3.55	10th
New environmental theories: toward a coherent theory of environmentally significant behavior.	STERN, Paul C.	2000	50	8th	2.38	16th
Are there social limits to adaptation to climate change?	ADGER, W. Neil *et al.*	2009	39	14th	3.25	14th
Students' understanding of the greenhouse effect, the societal consequences of reducing CO^2 emissions and the problem of ozone layer depletion.	ANDERSSON, Björn; WALLIN, Anita.	2000	46	11th	2.19	17th
Adaptive capacity and human cognition: the process of individual adaptation to climate change.	GROTHMANN, Torsten; PATT, Anthony.	2005	38	15th	2.38	16th
Vulnerability.	ADGER, W. Neil.	2006	37	16th	2.47	15th
The theory of planned behavior.	AJZEN, Icek *et al.*	1991	42	12th	1.40	19th
Risk perceptions, general environmental beliefs, and willingness to address climate change.	O'CONNOR, Robert E.; BARD, Richard J.; FISHER, Ann.	1999	35	18th	1.59	18th
The 'Greenhouse Effect': children's perceptions of causes, consequences and cures.	BOYES, Eddie; STANISSTREET, Martin.	1993	36	17th	1.29	20th

LEGEND: *Mean = total number of citations/number of years when the article was published.

SOURCE: Elaborated by the Authors, 2020.

Authors accounting for the largest number of publications were also analyzed. It was done by taking into consideration those who had two, or more, articles published under the same authorship. The most prominent names were Liu Q. Y., Peterson M. N., Stevenson K. T. and Yang J., who published 10 articles, each; they were followed by Hamilton L. C., who published 9 articles (Table 3).

In addition, Hamilton, L. C. and Leiserowitz, A. were the authors of the most cited articles; the first author ranked the 8th position in mean number of citations, whereas the second one ranked 13th the position in this same ranking. As for the most relevant researchers, the vast majority of authors focused on analyzing the investigated topics were foreigners. Leal W., who was born in Salvador City, Bahia State, stood out in Brazil, although his professional background comprises over 8 years in Germany, a fact that indicates another opportunity to make international institutional partnerships.

Moreover, there was remarkable growth in the number of publications on a yearly basis (Figure 1), in the last decade, since 36 articles were published in 2010; and 361, in 2019. In addition, 246 articles has already been published until August 2020, when the search was carried out. This finding has evidenced the remarkably increasing number of studies on CC associated with EE. It is essential emphasizing that the current study did not adopt any timeframe; the first article on the investigated topic was published in 1994.

With respect to article's origin, countries mostly publishing articles were the United States (638 articles; 34.5% of the total sample), Australia (approximately 10.5%), England (9.8%) and China (9.1%); they were followed by Germany (7.7%), Canada (7.2%), Spain (3.9%), Sweden (3.5%), Netherlands (2.9%), South Africa (2.9%), India (2.4%), Brazil (2.2%), among other less representative countries within the analyzed period (they accounted for 3.4% of the total sample).

There was prevalence of European and North American countries; however, developing countries have also appeared in this list. China, India and Brazil were the most representative ones (Figure 2).

TABLE 3 – Authors accounting for the largest number of publications about environmental education and climate change in the *Web of Science* database.

Authors	N. of articles
LIU QY	10
PETERSON MN	10
STEVENSON KT	10
YANG J	10
HAMILTON LC	9
SOVACOOL BK	7
WANG J	7
BELL ML	6
FEINSTEIN NW	6
KRASNY ME	6
LEAL W	6
MAIBACH E	6
MASUD MM	6
WILSON C	6
GOLD AU	5
GROSE J	5
HUANG CR	5
KELLER L	5
KHANAL U	5
LEISEROWITZ A	5
LIU XB	5
LOMBARDI D	5
LUNDHOLM C	5
MAIBACH EW	5
MONROE MC	5

SOURCE: *Web of Science*, 2020.

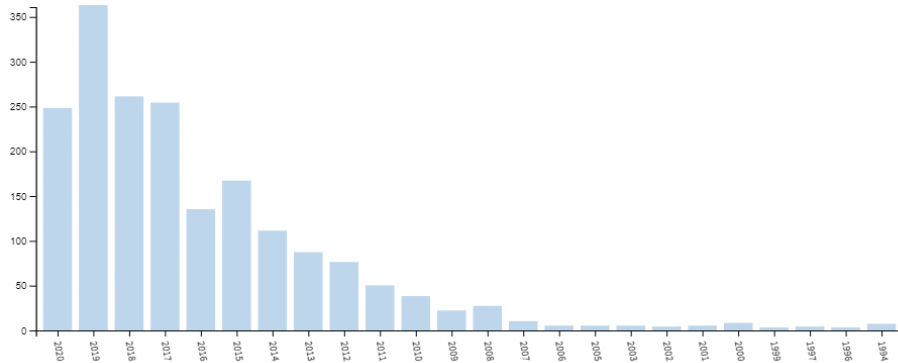Desenvolv. Meio Ambiente, v. 61, p. 391-410, jan./jun. 2023.

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FIGURE 1 – Number of studies about environmental education and climate change published in the *Web of Science* database on a yearly basis.
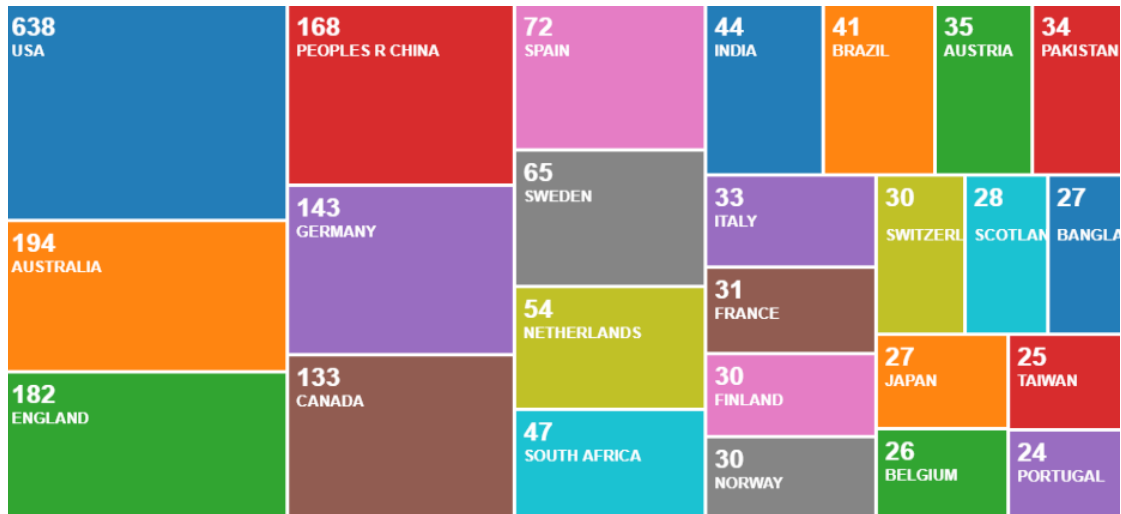SOURCE: *Web of Science*, 2020.

FIGURE 2 – Studies about environmental education and climate change published per country of origin in the *Web of Science* database.
SOURCE: *Web of Science*, 2020.

Brazil's position - 41 articles; 12th position in the ranking of countries that have mostly published in the analyzed period – has evidenced increased number of studies on CC and EE conducted in the country. Accordingly, 24.4% of these publications were linked to University of São Paulo (USP) and 9.75%, to State University of Campinas (Unicamp) - they were the main national institutions publishing on this topic -; 28 articles (68.3%) were published in English; 13, in Portuguese (31.7%), and 1, in Spanish (2.4%).

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The main topics addressed in Brazilian publications comprised EE (17.1%; 7 articles), climate education, sustainability and environmental perception (12.2%; 5 articles, each); all together, they accounted for 53.7% of the total number of published articles (Table 4).

Four articles about EE and 4 about climate education - which were in compliance with the research aim - were herein used among 13 topics addressed in Brazilian publications (Figure 4), as shown in Table 5.

TABLE 4 – Main topic addressed in Brazilian studies about environmental education and climate change publishedin the Web of Science database.

Topic	N. of articles
Environmental education	7
Climate education	5
Sustainability	5
Environmental perception	5
Biodiversity	3
Sustainable development	2
Ecology	2
Environmental vulnerability	2
Social representations/ adaptation to the climate	2
Climate technologies	2
Climate change impacts	2
Public policy	3
Anthropocene	1

SOURCE: Elaborated by the authors, 2020.

TABLE 5 – Research about environmental education and climate education in Brazilian studies published in the *Web of Science* database.

Title	Author	Journal	Year
Arborização Urbana do município de Itapira – SP: perspectivas para educação ambiental e sua influência no conforto térmico [Urban afforestation in Itapira County - SP: perspectives for environmental education and its influence on thermal comfort]	MARTELLI, Anderson; SANTOS JÚNIOR, Arnaldo Rodrigues	Revista Eletrônica em Gestão Educação e Tecnologia Ambiental [Electronic Journal on Environmental Management, Education and Technology]	2015
Quais seriam as Questões Globais que desafiam a Educação Ambiental? Para além do modismo, uma análise sistemática e uma visão sistêmica [What are the Global Issues challenging Environmental Education? Beyond fads, systematic analysis and systemic view]	SAITO, Carlos Hiroo	Revista Eletrônica do Mestrado em Educação Ambiental [Electronic Journal of the Master's Degree Course in Environmental Education]	2017
La educación estético-ambiental como un imperativo de la educación en las condiciones de la crisis socio-ambiental contemporânea [Aesthetic-environmental education seen as imperative factor for education under the contemporary socio-environmental crisis conditions]	ALVAREZ Lurima Estevez; SCHMIDT Elisabeth Brandao; ESTÉVEZ Pablo Rene	Revista Eletrônica do Mestrado em Educação Ambiental [Electronic Journal of the Master's Degree Course in Environmental Education]	2017

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O papel da Educação Ambiental na discussão das Mudanças Climáticas: caracterização a partir de um espaço dialógico entre pesquisadores em ecologia e docentes em ciências [The role played by Environmental Education in Climate Change debates: featuring process in the dialogical space between ecology researchers and science teachers]	MONIZ BENAC, Raquel dos Santos; FREIRE, Laisa Maria	Revista Eletrônica do Mestrado em Educação Ambiental [Electronic Journal of the Master's Degree Course in Environmental Education]	2018
Implementing climate change research at universities: Barriers, potential and actions	LEAL FILHO, Walter *et al.*	Journal of Cleaner Production	2018
International perspectives on the pedagogy of climate change	PERKINS, Krystal M.	Journal of Cleaner Production	2018
Climate Change Skepticism at Universities: A Global Study	LEAL FILHO, Walter *et al.*	Sustainability	2019
Climate change education in school: knowledge, behavior and attitude	ROCHA, Vanessa Tibola; BRANDLI, Luciana Londero; LOCATELLI KALIL, Rosa Maria	International Journal of Sustainability in Higher Education	2020

SOURCE: *Web of Science*, adapted by the authors, 2020.

With regard to Brazilian publications on climate education (Table 4), Leal Filho was the author accounting for the largest number of publications (two studies). His first study addressed barriers, potentials and actions associated with CC research implementation in universities; it was published in the *Journal of Cleaner Production*. His second study was a global survey on CC-related skepticism in universities; it was published in *Sustainability*, which is the journal accounting for most of the titles in this field (Table 1).

The largest number of articles about EE (Table 4), in the CC context, was published in the Electronic Journal of the Master's Degree Course in Environmental Education (three studies; 75% of the sample). The first study addressed the global issues challenging EE; the study by Saito, C. H. (2017) about CC stood out from this perspective. The second study presented EE as imperative factor for education under the contemporary socio-environmental crisis conditions; Alvarez, L. E., (2017)

was its main author. The third study, conducted by Moniz Benac, R. S. and Freire, L. M. (2018), addressed the role played by EE in the CC scenario, based on "dialogue" between ecology researchers and science teachers.

Institutions publishing the largest number of studies on the investigated topic encompassed University of California System (50 articles), State University System of Florida (39 articles), University of North Carolina (30 articles), among others with greater uniformity and less representativeness in number of studies. No Brazilian institution was observed among the ones mostly publishing studies on the investigated topic (Table 6).

With respect to publication language, 97.62% of articles were written in English; 1.24%, in Spanish; 0.92%, in Portuguese; and few articles were written in other languages (0.2%). This outcome was expected, given the high accessibility of studies published in English and the requirement of international journals.

4.2. Analysis mapping carried out in VOSviewer software

Twenty-one (21) of the 78,387 studies cited in the analyzed articles received at least 35 simultaneous citations (Figure 3). It is worth clarifying that the size of the circles is proportional to the number of citations and that each color refers to the cluster created by the software itself. There was little difference in clusters' size and centrality.

The cluster highlighted in red refers to articles about public's reasoning ability and scientific communication on CC, ideological and partisan polarity in CC issues and individuals' perceptions about CC: Kahan et al. (2012), McCright & Dunlap (2011), Lee *et al.* (2015) and Leiserowitz (2006) - it explains why their studies were the most cited ones.

According to Leiserowitz (2006), Americans' risk perceptions and support to politics are instigated by experiential factors, such as affection, images and values; it shows that public responses to CC are influenced by psychological and sociocultural aspects. Furthermore, according to Lee *et al.* (2015), overall, approximately 40% of adults worldwide were unaware of CC. Formal education was the greatest individual knowledge predictor among those aware of CC, since it provided instructions capable of increasing the measured levels of both awareness and concern about CC.
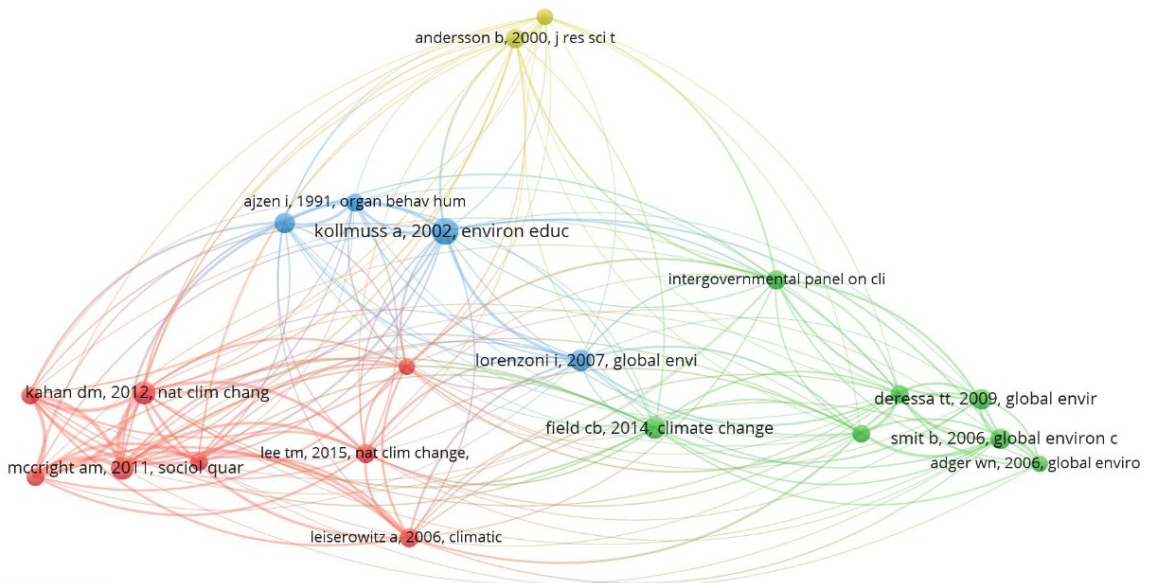

FIGURE 3 – Co-citation mapping of references on environmental education and climate change in the *Web of Science* database.
SOURCE: *Web of Science*, 2020.

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The cluster highlighted in blue comprised studies by Lorenzoni I. *et al.* (2007), Kollmuss & Agyeman (2002) and Ajzen (1991), who addressed political implications of CC, barriers to pro-environmental behavior, as well as organizational behavior and human decision-making processes, respectively. The cluster highlighted in green mainly addressed the analysis of efficiency in education in universities; its main authors were Field & Barros (2014). The cluster highlighted in yellow, which comprised the study by Andersson (2000), who carried out a national assessment to help improving Science teaching and science education, based on research contributions.

Co-authorship analyses were carried out based on country and institution in order to investigate the frequency of networks or interactions between authors who perform studies about CC within the education and/or EE scopes. Studies forming the sample were conducted in 127 different countries; at least 30 published articles were selected.

Circles' size is proportional to the number of publications. The most extensive networks were found the United States, Australia and England. Brazil accounted for 41 published articles and recorded interactions with the United States, United Kingdom, Germany, Australia, Mexico and Sweden (Figure 4).
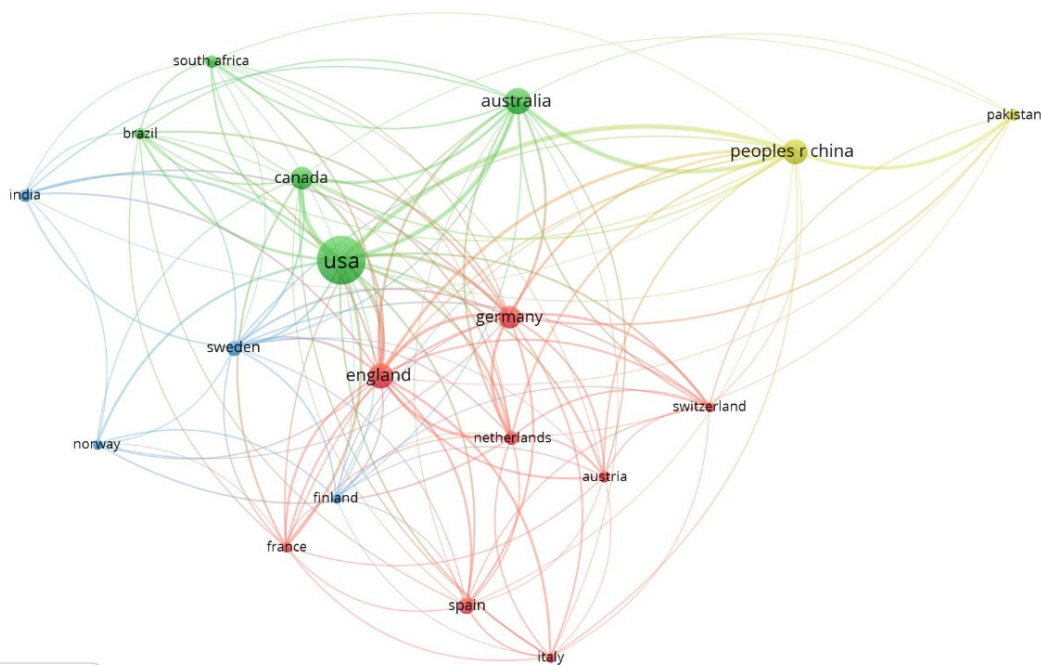

FIGURE 4 – Mapping of co-authorship in studies about environmental education and climate change published in the *Web of Science* database, on a yearly basis.

SOURCE: *Web of Science*, 2020.

Among all 2,161 institutions forming the sample, at least 15 articles were taken into consideration for the analysis of interactions between those who mostly published studies on the investigated topic. The size of the circles corresponds to the number of connections to other institutions; color identifies each of the three clusters. The apparent name corresponds to the institution with the largest number of connections (Figure 5).

Organizations standing out for the decreasing number of connections were University of Colorado and Michigan State University (6); Chinese Academy of Sciences (5); University of Florida and Cornell University (4); University of British Columbia (3); University of Wisconsin; University of California, Berkeley; and Pennsylvania State University (2), Monash University (1).

No Brazilian university appeared on the map; however, USP and Unicamp are the Brazilian institutions accounting for largest number of publications in the country, a fact that highlights the relevance of making partnerships with other institutions, even with institutions from other countries, to develop research and improve knowledge.

Finally, the analysis applied to the co-occurrence of keywords enabled finding the main terms used in studies forming the sample: 26 terms of the total number of 7,089 keywords were repeated at least 60 times (Figure 6). The size of circles in the map of the main keywords is proportional to the number of occurrences of the investigated expression; proximity between words is associated with the number of times they occurred together - each color corresponds to one cluster suggested by the software.
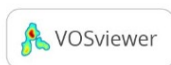

FIGURE 5 – Mapping of co-authorship in studies about environmental education and climate change published per institution on the *Web of Science* database.
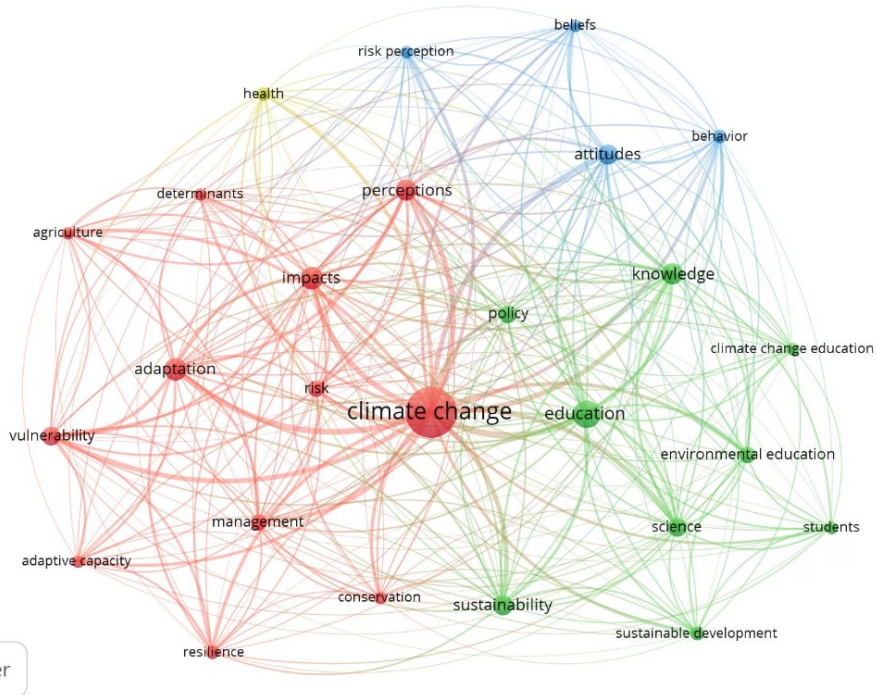
SOURCE: *Web of Science*, 2020.

FIGURE 6 – Mapping of keywords' co-occurrence in studies about environmental education and climate change published in the *Web of Science* database.
SOURCE: *Web of Science*, 2020.

The size and centrality of the largest circle, in the cluster highlighted in red, shows the relevance of the term "climate change", as expected. The following expressions are directly linked to CI: "impacts", "adaptation", "perceptions" and "vulnerability". It is worth emphasizing the green cluster, wherein the term "education" is linked to terms such as "knowledge", "sustainability", "science", "students", "policy", "sustainable development", "environmental education" and "climate change education" - this link highlights the role played by CC in the EE scenario.

Expressions that were not directly linked to the research topic appeared in the other clusters. The blue cluster presented terms such as "attitudes", "behavior", "risk", "perceptions" and "beliefs", whereas the yellow cluster presented the term "health".

Accordingly, it was possible seeing that publications about CC and EE were associated with studies on impacts, vulnerability, adaptation, sustainable development, sustainability and perceptions about environmental issues; and, on a smaller scale, with studies about risks, behaviors, attitudes and decision-making by individuals in society. However, it is important highlighting the progress achieved in research focused on public policies and climate education.

5. Final considerations

The term "climate change" got significant attention in recent years, mainly from 2017 onwards: more than 350 articles about this topic were published in 2019 and, by August 2020, more than 250 publications were observed. The importance of EE was evidenced in studies on CC. The evolution of research on this topic in the education, environmental sciences, public policies, ecology, technology and meteorology fields was also observed in the last 26 years.

In addition to this quantitative increase, it is worth mentioning the quality of the assessed articles, if one takes into account the quality of the five journals accounting for the largest number of publications, i.e., Qualis A1 in Environmental Sciences and Education. This finding has evidenced the expansion of studies on CC and researchers' interest in working with topics associated with EE.

Studies conducted in the aforementioned fields presented low level of institutional partnerships, although it is fundamental developing inter-institutional and multinational research in the current context. This process directly applies to the Brazilian institutions accounting for the largest number of publications in the country – i.e., USP and Unicamp -; they enable the advancement of international partnerships.

The analyzed studies were mainly concentrated in the United States and in European countries; however, there was increase in the number of research and different countries, such as China, South Africa, India and Brazil have gained prominence in this field. English was the prevalent language in the analyzed studies. Furthermore, the main authors were not those who published the most recent studies; they were the ones accounting for the largest number of studies and citations, and who had strong connection to other authors.

More than half (68.3%) of Brazilian publications were written in English, a fact that can increase foreigners' access to these articles. The increased number of publications and CC's strong links to research terms such as education, perception, attitudes, sustainability, impacts and vulnerability.

It was possible concluding that the herein addressed topic did not emerge recently, despite the progress observed in studies about it in the last decade. Moreover, it has the potential to help studies and applications in education to find CC mitigation and adaptation measures. Therefore, climate education and the approach to CC in school context should be further investigated in other databases, by taking into consideration the application of EE elements in CC issues associated with anthropic actions. Most importantly, the association between basic education quality indicators and EE implementation focused on CC in schools from developed and underdeveloped countries should be also addressed in future studies.

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