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Environmental education for fire prevention in the world: A literature review[1]

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Abstract: Environmental education fosters environmentally literate citizens capable of addressing sustainability challenges. This article presents a literature review on environmental education and how fire-related topics are approached in primary education worldwide. The review combined quantitative bibliometric analysis and a qualitative systematic review supported by Artificial Intelligence, using Scopus and Web of Science databases. A total of 16,421 articles were identified since 1968, with 4,065 duplicates removed. The annual growth rate of publications was 11.43%. Female researchers ranked highest in productivity and impact (H-index). Core themes in environmental education include climate change, biodiversity, waste management, and ecology. However, only 0.152% of all documents addressed fire education in schools and universities. Most fire-related studies focused on prevention, safety, and forest fire suppression.
Keywords: Environmental learning. Sustainable development. Bibliometrix. Climate change.

Educación ambiental para la prevención de incendios en el mundo: una revisión de la literatura

Resumen: La educación ambiental fomenta ciudadanos ambientalmente alfabetizados, capaces de afrontar los desafíos de la sostenibilidad. Este artículo presenta una revisión de la literatura sobre

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educación elemental y cómo se abordan los temas relacionados con el fuego en la educación primaria a nivel mundial. La revisión combinó un análisis bibliométrico cuantitativo y una revisión sistemática cualitativa apoyada por Inteligencia Artificial, utilizando las bases de datos Scopus y Web of Science. Se identificaron un total de 16.421 artículos desde 1968, con la eliminación de 4.065 duplicados. La tasa anual de crecimiento de las publicaciones fue del 11,43 %. Las investigadoras ocuparon los primeros lugares en productividad e impacto (índice H). Los temas centrales en educación ambiental incluyen el cambio climático, la biodiversidad, la gestión de residuos y la ecología. Sin embargo, solo el 0,152 % de todos los documentos abordó la educación sobre el fuego en escuelas y universidades. La mayoría de los estudios relacionados con el fuego se centraron en la prevención, la seguridad y la supresión de incendios forestales.
Palabras-clave: Aprendizaje medioambiental. Desarrollo sostenible. Bibliometría. Cambio climático.

Educação ambiental para a prevenção de incêndios no mundo: uma revisão da literatura

Resumo: A educação ambiental fomenta cidadãos ambientalmente alfabetizados, capazes de enfrentar os desafios da sustentabilidade. Este artigo apresenta uma revisão da literatura sobre a educação básica e sobre como os temas relacionados ao fogo são abordados no ensino fundamental em escala mundial. A revisão combinou uma análise bibliométrica quantitativa e uma revisão sistemática qualitativa apoiada por Inteligência Artificial, utilizando as bases de dados *Scopus* e *Web of Science*. Foram identificados, ao todo, 16.421 artigos desde 1968, com a eliminação de 4.065 duplicatas. A taxa anual de crescimento das publicações foi de 11,43%. As pesquisadoras ocuparam as primeiras posições em produtividade e impacto (índice H). Os temas centrais da educação ambiental incluem mudança climática, biodiversidade, gestão de resíduos e ecologia. No entanto, apenas 0,152% de todos os documentos abordaram a educação sobre o fogo em escolas e universidades. A maioria dos estudos relacionados ao fogo concentrou-se na prevenção, segurança e supressão de incêndios florestais.
Palavras-chave: Aprendizagem ambiental. Desenvolvimento sustentável. Bibliometria. Mudança climática.

INTRODUCTION

Increased consumption of natural resources has contributed to a scenario of changes in the human-nature relationship. Thus, according to Barnosky & Hadly (2016), around the world, environmental conditions are deteriorating at an alarming rate due to an intricate web of socio-ecological challenges, which include, among others, climate change, air and water pollution, ocean acidification, soil degradation, and biodiversity loss. In addition, evidence of ecosystem destruction, human-induced climate change, social injustice, and growing socioeconomic conflicts is increasing in many parts of the world (Reddy, 2021). It is, therefore, imperative to include environmental education in debates about environmental changes.

Thus, environmental education, also understood as education for sustainable development or environmental learning, regardless of the conceptualization, aims to create an environmentally literate citizenry suitable for addressing sustainability (Ardoin and Bowers, 2020) in addition to contributing to changing student behavior

(Hungerford & Volk, 1990). Furthermore, this possibility of analysis plays a significant role in the future of humanity (Nousheen *et al.*, 2020). Added to this is the fact that it is necessary to think about the goals set for Education for Sustainable Development (ESD) and Education for Sustainable Development Goals (ESDG) (Kopnina, 2020), which are considered challenges for sustainability.

According to Alvorada *et al.* (2023), environmental education interventions must follow science-based standards, be comprehensive, and be part of an integrated and practical strategy. This strategy must include preventive measures and sustainably address environmental health issues. This is relevant because, according to Ardoin and Heimlich (2021), teaching in the environmental context is a continuous and profound effort throughout life.

This possibility for education, even in elementary school, is relevant because it is a transdisciplinary challenge in the contemporary world to recognize the problems faced by humanity, including pollution, water scarcity, forced migration, poverty, environmental crises, and the destruction of the social fabric (Max-Neef, 2005). Thus, environmental education is expected to increase pro-environmental knowledge and behavior, but little attention is usually paid to satisfying students' emotional needs, even in childhood (Baker *et al.*, 2021). Ardoin, Bowers, and Gaillard (2020) argue that environmental education creates productive spaces for research. For Ardoin and Bowers (2020), environmental education focused on the early years of childhood is experiencing dynamic growth in research and practice due to persistent environmental challenges, along with growing interest in the documented benefits of rich experiences in nature for infants and toddlers. In this context, forest fires' socio-economic and environmental impacts worldwide stand out, including their influence on climate change (Fargeon *et al.*, 2020).

Despite the disturbances caused by forest fires, fire is an integral part of many ecosystems (Feitosa Junior, 2024). According to Wunder *et al.* (2021), this becomes relevant because extreme forest fire events should be analyzed as severe problems.

In this context, Edwards *et al.* (2021) state that preserving the environment and preventing fires have emerged as concerns in recent decades worldwide. According to Ardoin and Bowers (2020), environmental education is key in making communities aware of wildfire risks and promoting sustainable practices to reduce their incidence and impact. To this end, practical educational approaches involve raising public awareness,

such as training community leaders (Cincera *et al.*, 2020), integrating traditional and scientific knowledge (Abreu *et al.*, 2017), and developing practical skills to deal with emergencies (Shah *et al.*, 2020). In addition, the topic becomes more relevant because, in general, forest fires generate profound social, environmental, and economic burdens (Carmenta *et al.*, 2021).

To this end, environmental education must play a relevant role in thinking about fire occurrence, its sociais, environmental, and economic impacts, and the prevention of forest fires. For this to occur, individuals and communities must be empowered to understand the principles of fire ecology, recognize the risks associated with wildfires, and adopt responsible behaviors to reduce their occurrence. In this sense, this article aims to present a literature review on environmental education and how approaches to studying fire are carried out in primary education worldwide. Similar research has been recurring, among which the studies by Ardoin, Bowers, and Gaillard (2020) carried out a literature review to analyze environmental education aimed at biological conservation. Ardoin and Bowers (2020) also applied this analysis to the study of environmental education in early childhood. For the authors, connection with nature is vital for the healthy socio-emotional development of children.

MATERIALS AND METHODS

The literature review combined the quantitative perspective through the bibliometric and qualitative review based on the systematic review. Therefore, from a bibliometric perspective, Artificial Intelligence was applied to search the Scopus and Web of Science databases. From a bibliometric perspective, documents were selected for the systematic review. Thus, the term fire was defined as a thematic focus based on the title of the documents. Subsequently, a new selection of texts referred only to primary education (elementary and secondary education).

The systematic approach aimed to identify the text's target audience (age) and whether the approach was applied to fire prevention. In addition, based on immersion practices, the location of the actions was observed, whether in the school or the community.

In addition to the above, the following steps were applied to these perspectives, (1) definition of the search string, in this case, the term “Environmental education,” with the use of quotation marks, (2) search through the Portal of Periodicals of the

Coordination for the Improvement of Higher Education Personnel (CAPES) in Brazil, (3) processing of the data obtained from the databases, in bib format, in the R software, version 4.2, using the Bibliometrix package and exporting it to the Biblioshiny web interface, (4) statistical analysis in Biblioshiny (Aria and Cuccurullo, 2017), (5) selection, by consulting all the documents found for the systematic review.

Notwithstanding the analysis in Biblioshiny (Bx), Feitosa Junior *et al.* (2024) argue that the interface carries out an analysis of four metrics at different levels (Sources, Authors, Documents, and Clustering); the analysis of three Knowledge structures (Conceptual Structure, Intellectual Structure, and Social Structure), observed the integrity of the metadata through its completeness, classified as 'excellent,' 'good,' 'acceptable' and 'completely absent.' Only the documents classified as 'excellent' and 'good' in the completeness analysis, which guided the bibliometric indicators selected for this review, were valued in the analysis. Finally, to reduce the number of documents for statistical analysis, those in the top 10 (authors, most cited documents, among others) were highlighted.

RESULTS

The primary information presented by Bx revealed 7,555 articles for Web of Science and 12,931 for Scopus, amounting to 16,421 articles published between 1968 and 2024, excluding 4,065 duplicate articles in the two databases. Although the Bx tool is responsible for selecting the articles, this research has moved on to the systematic perspective, presented in the second part of the results.

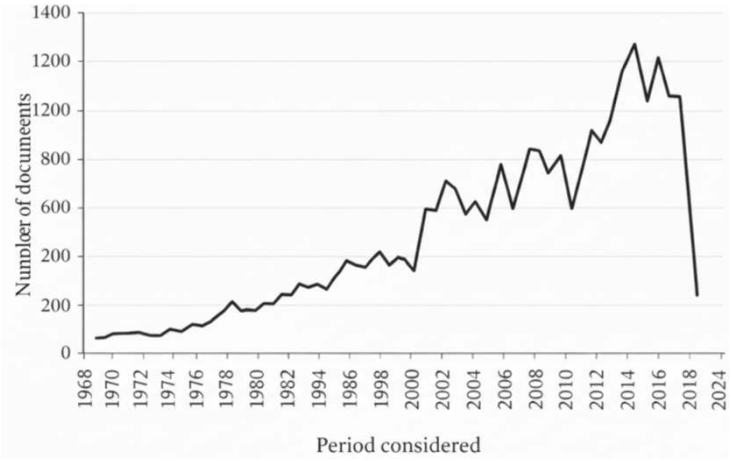
From a bibliometric perspective, the results showed the production of 31,229 authors with international co-authorship of around 6.924%. An average of 2.82 authors per article and approximately ten documents cited per article. The articles selected (n = 16,421) in the period considered had an average publication age of 12.2 years.

The completeness of the bibliographic metadata revealed that of the total produced by Biblioshiny, six were considered excellent, two were considered good, one acceptable, three were considered poor, one critical, and two absent. The most affected parameters, classified as totally absent, were the number of references cited and scientific categories.

Figure 1 shows the evolution of the number of environmental education studies worldwide. It can be seen that until 1988, the number of publications remained stable

and low. There was a slight increase in 1998, but the number of publications increased more sharply from 2008 onwards. Overall, the production growth rate is approximately 11.43%.

Figure 1. Annual Scientific Production evolution.



Source: Prepared by authors (2024).

In general, 51 words were highlighted, with a more significant predominance of the word 'environmental education' with 2,957 (18%) mentions, followed by the word 'education' with 1,097 (7%) and 'sustainable development' with 674 words (4%). The words ‘knowledge’ and ‘students’ also appear in the list. In addition to the above, words stand out that reveal concern about some themes, for example: ‘climate change’, ‘biodiversity’, ‘forestry’, ‘waste management’ and ‘ecology’. Notably, the word ‘fire’ does not appear in the list.

It is essential to highlight that there was an omission error regarding the most cited institutions, resulting in 131 documents marked as "NOTREPORTED." Of the remaining nine institutions, six are located in the United States, one in Brazil (the most prominent institution with the most significant number of documents produced), one in Australia, and one in Spain. The University of São Paulo, one of Brazil's most prominent universities, has seen the highest rate of growth in the number of publications among the institutions analyzed, especially since 2019. Stanford University is second, followed by Monash University.

In this context, the United States, Brazil, and China lead the top 10 in terms of number of publications. However, regarding impact, the United States, the United Kingdom, and Australia occupy the first three positions in the top 10. Sweden is among

the ten most cited countries, but it does not appear on the countries with the highest production impact list.

The Bx also shows the evolution of the production number over the years. In this sense, Brazil has shown substantial growth since 2019. In this analysis, the United Kingdom has stabilized its production, and China has thrived, albeit slower than Brazil's production growth rate.

Another way of analyzing the relationship between authors from different countries worldwide. Single Country Publications (SCP) and Multi Country Publications (MCP) are more numerous in the United States of America, Brazil, and China, respectively. These results consolidate the ranking of the most prominent countries in producing knowledge on environmental education. It can be seen that Brazil has many publications by national authors. However, collaboration with other countries is equivalent to that of China, which has fewer publications exclusively by authors from its own country.

A collaboration between researchers from different countries revealed the interaction between continents, with the intensity of the interaction between the United States of America, Brazil, China and Europe.

The journals with the highest H Local Impact indexes: Environmental Education Research stands out as a bimonthly international forum for critical and constructive debate on all aspects of research, theory, and praxis in environmental and sustainability education and related areas. Next on the list is the Journal of Environmental Education, Journal of Cleaner Production, an international and transdisciplinary journal focusing on research and practices in cleaner production, the environment, and sustainability. Also noteworthy in this regard is that the journal Environmental Education Research has seen a sharp increase in the number of publications on environmental education since 2016. This phenomenon placed it in an isolated position from this period onwards, and it is currently the leading journal on the subject.

The principal authors, by the number of published articles and H index is Marianne E. Krasny stands out (H index = 22), and in the number of articles, researcher Annette Gough (54 articles mapped). The curious fact was the presence, on both lists, of researchers Marianne E. Krasny, Philip Payne, Bogner Franz, Nicole M. Ardoin, Annette Gough, Helen Kopnina, and Arjen E.J. Wals. Furthermore, the majority of the list are women.

The list of the most cited documents was organized in Chart 1, highlighting the top ten. The table was structured to emphasize titles, author names, magazines, and years of publication. The most cited document was published in 2007 in the Journal of Environmental Psychology.

Chart 1. List of the most cited documents.

Title	Authors	Journal/Year
Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour	Sebastian Bamberg and Guido Mo¨ser	Journal of Environmental Psychology (2007)
Changing learner behavior through environmental education	Hungerford, Harold R. Volk, Trudi L.	The Journal of Environmental Education (1990)
Extinction of experience: the loss of human–nature interactions	Masashi Soga, Kevin J Gaston	Frontiers in Ecology and a Environmental (2016)
The current state of citizen science as a tool for ecological research and public engagement	Janis L. Dickinson, Jennifer Lynn Shirk, David N Bonter, Rick Bonney	The Ecological Society of America (2012)
International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review	Dirk Xanthos 1, Tony R Walker	Mar Pollut Bull (2017)
Predictors of public climate change awareness and risk perception around the world	Tien-ming Lee, E. Markowitz, P. Howe, Chia-Ying Ko, A. Leiserowitz	Environmental Science, Education
Shifting public opinion on climate change: an empirical assessment of factors influencing concern over climate change in the U.S., 2002-2010	Brulle, Robert J.; Carmichael, Jason; Jenkins, J. Craig	Climatic Change
Conservation social science: Understanding and integrating human dimensions to improve conservation	N. Bennett *et al.*	Environmental Science, Sociology Biological Conservation
Foundations of transdisciplinarity	Manfred Max-Neef	Ecological Economics
Scepticism and uncertainty about climate change: Dimensions, determinants and change over time	Lorraine Whitmarsh	Global Environmental Change

Source: Prepared by authors (2024).

The systematic review revealed that the number of documents (a total of 25 units) detailing didactic-pedagogical experiences on fire in the context of environmental education research worldwide is small. In other words, of all the documents in the bibliometric perspective on environmental education, only 0.152% dealt with the theme of fire in teaching institutions. Despite this, these documents reveal experiences of projects carried out in various countries spreads across four continents.

Of the 25 documents, ten present concrete experiences of fire study projects for primary education, and five refer to projects applied to higher education students. The others study fire in primary education and state that the research results can be applied to environmental education.

Concerning the perspectives of the studies selected for a systematic approach, it was possible to see a preference for fire analyses focused on the prevention, safety, and suppression of forest fires. These studies aim to reduce the risk of forest fires, especially in areas with an interface between town and countryside. Other approaches value studies that analyze the history of fire occurrence, seeking to take advantage of previous experiences with forest fires. Few studies focus on the ecology of fire and its positive role in ecosystems. In addition, some studies highlight the importance of scientific literacy about forest fires.

Also noteworthy are the studies that value the perspective of school communities' perceptions of fire. Of the studies not directly associated with actions with elementary school students, it was possible to see a perspective of producing data that can be used in schools. In other words, they are studies in which the authors reveal that their data can be applied to environmental education.

Methodological studies on primary education have used a variety of strategies. These include long-term projects, content analysis of children's representations and perceptions, photographic, questionnaires, and interviews. In addition, projects have been carried out through camps and field trips, providing students with immersion in the outdoors and classroom activities, including visits from experts in the field, such as members of the fire brigades. Also noteworthy are the environmental education projects focused on fire, which use partnerships between schools, communities, and state agencies to give talks and collect fire data. Other studies, which did not directly involve schools, applied mapping methodologies using geotechnologies and statistical models.

Regarding the results achieved, the documents unanimously state that environmental education on this subject contributes to forming more aware citizens. This becomes even more relevant when the subject is included in school curricula. Finally, we observed that fire-related environmental education studies have predominantly local approaches. Thus, they are projects focused on schools and the community in isolation. Only two documents report experiences between states within a

country, and one document compares experiences between a European country and an African country.

DISCUSSION

In general, our results reveal a continuous growth in environmental education over time, which began in the 1990s and has continued since then. This growth can be attributed to various factors. Firstly, it is possible to observe that the years leading up to the 1990s revealed a significant expansion of global environmental organizations, both governmental and non-governmental, along with an explosion in global discourse and communication on environmental problems (Meyer *et al.*, 1997).

In this context, the major environmental conferences stand out, including the Kyoto Protocol, within the framework of the Conference of the Parties to the Convention, which lays down some specific obligations for developed states and states in the transition to a market economy (Scovazzi, 2021). The main objective of the Kyoto Protocol was to establish concrete targets for the reduction of anthropogenic emissions of six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride), aiming for an overall reduction of at least 5% compared to 1990 levels (Scovazzi, 2021). In addition, the Rio de Janeiro Conference, Eco92, which regulated the specific multilateral treaty, focused on climate change.

Also, in this context, the growth of scientific production on environmental education in the world can be explained by the accelerated process of anthropization and its discussion, especially urbanization in the world, or the increase in the percentage of people living in cities, which peaked in the late 1980s (around 87 million per year) (Buhaug and Urdal, 2013). For the authors, the rapid growth of urban populations places significant demands on the capacity of societies to provide public services such as adequate housing, electricity, water, healthcare, education, and jobs (Buhaug and Urdal, 2013). This happens in practically every country, intensifying a scenario of permanent conflict and occupying a central place in the environmental debate that directly affects everyone's lives.

Faced with this scenario, there are growing popular demands for democratic and economic reforms (Buhaug and Urdal, 2013), which reflects on awareness of the

importance of environmental preservation and issues such as global warming (Pașcalău *et al.*, 2021), loss of biodiversity (Ardoin *et al.*, 2020) and pollution. These topics have generated increased interest in this field of teaching and research. For example, Velasco-Martínez *et al.* (2020) evaluated the effectiveness of a teaching program for Spanish students on the effects of climate change on our consumption model and waste generation. These results revealed that students were convinced that adopting minimum pro-environmental habits can help mitigate climate change, which denotes the importance of education for environmental awareness.

Furthermore, the impacts of climate change are transboundary, not respecting the territorial and political boundaries of states. This shows that joint action between governments and society is more than necessary to mitigate the consequences and adopt practices that aim to achieve a balance between human activities and the environment (Espínola and Ribeiro, 2020).

Another example is the public policies and regulations promoted by governments and international organizations that encourage environmental education, including its inclusion in school and university curricula. In addition, increased funding and support for research in the environmental field contribute significantly to the growth of publications. International collaboration and easier access to computer networks also play an essential role in rapidly disseminating and sharing data and results from environmental studies (Feitosa Junior *et al.*, 2024).

Based on the results obtained for the keywords, a strong relationship was observed between the terms “environmental education,” “education,” and “sustainable development.” This shows that the keyword choice for the literature review was right, as it favored obtaining new, relevant, and more influential research (Kraus *et al.*, 2022). This direct relationship highlights the importance and interconnectedness between these concepts, underscoring the relevance of environmental education as a crucial component in promoting sustainable practices. These findings reinforce the idea that environmental education is not just an academic topic but an essential need for contemporary society. It plays a fundamental role in shaping citizens aware of and committed to preserving the environment and developing sustainable practices.

Concerning the results of the nine leading institutions in environmental education studies, there was a predominance of institutions located in the United States of America. However, the University of São Paulo (USP) ranks top. This institution, one

of Latin America's largest and most influential universities, highlights Brazil's significant contribution in this area. It is also important to mention that USP is considered Brazil's largest higher education institution (Dias and Porto, 2014) and was founded in 1934. USP's actions favoring environmental education were the subject of a study by Silva and Bacci (2024). According to the authors, since 1986, different events and experts have emphasized the importance of the University's participation in formulating interdisciplinary solutions to environmental issues in Brazil, influenced by events held in various countries. In this regard, the World Conference on the Human Environment (Stockholm Conference) in 1972 and the Second World Conference on Environment and Development, known as Eco-92, stand out, among others.

In addition, USP's leading role can be linked to the fact that, in Brazil, specific legislation dating back to 1981 created the National Environmental Policy (Portugal & Sorrentino, 2020). In addition, in the historical context, Brazilian society has undergone significant transformations: rapid population growth driven by the industrialization process has increased the demand for natural resources, causing severe risks to the environment; in urban centers, precarious sanitation conditions have been accentuated (Oliveira, 2021).

Furthermore, of the ten institutions listed, six are located in the United States of America. This reflects the country's leadership in academic research into environmental education worldwide. However, this aspect can be considered contradictory since consumption in the United States has not always been sustainable and has been promoted without respect for environmental resources (Furriela, 2001). According to Furriela (2001), the challenge is to abandon the throwaway society and excessive consumption, rejecting the American dream as synonymous with well-being and happiness.

Despite this, it was possible to identify successful initiatives by the North American Association for Environmental Education (NAAEE) and its 56 state, provincial, and regional affiliate organizations in the United States, Canada, and Mexico. Also noteworthy was the Environmental Education Act of 1970, which created the Office of Environmental Education to implement this issue for ten years. Later, in 1971, the National Association for Environmental Education was formed and renamed the North American Association for Environmental Education (Disinger, 2001). For the

author, North American schools play a fundamental role in effectively promoting environmental education for responsible citizenship.

In this context, the Journal of Environmental Education began publishing environmental education materials in 1969, indicating the need for this topic (Lee *et al.*, 2021). This occurred in the United States by including an environmental education program in the school curriculum (Lee *et al.*, 2021). Thus, given this reality, experiences in environmental education are widely identified in US literature, such as climate change education as a topic of study addressed in elementary school (Monroe *et al.*, 2019). This is favorable, as educational environments offer an opportunity to help children deal with the concerns of modern society (Clayton *et al.*, 2023).

For Dias and Gomes (2022), this aspect also refers to the denunciations of the consequences of the way of life adopted by modern society about the environment and reflections on the relationship between man and nature. In addition, environmental education for decision-makers in the United States is related to well-being, as spending time outdoors is a way of exploring open environments to improve health and coexistence (Safdie, 2024).

This result reflects the leading role played by the United States of America in terms of the number of documents produced and their impact. This may be related to the country's global leadership in scientific production in various areas (Kennedy *et al.*, 2022). Furthermore, for Feitosa Junior *et al.* (2024), global scientific production generally reveals the coloniality of knowledge centered on the countries of the northern hemisphere. Some aspects are listed for this, including the mechanisms for evaluating research valued more globally and using English as a global academic language that favors academics from English-speaking countries (Feitosa Junior *et al.*, 2024). In this sense, documents written in English are more likely to be consulted. Despite this, Schöpf (2020) states that there is a lack of comprehensive reports on the mechanisms that create and reinscribe academic dependency and favor the coloniality of knowledge.

The language issue can be used as an argument to discuss Brazil's role in ranking second in terms of a number of documents, but with a lower impact than other countries. According to Meneghini (2012), poor proficiency in written English, the lingua franca of modern science, is an obstacle to publishing in international journals, which generally have a higher impact.

In addition, it is essential to mention that Brazil uses its metric, called 'Qualis,' under the responsibility of the Coordination for the Improvement of Higher Education Personnel (CAPES). This metric is used to evaluate and measure the quality of scientific journal articles. The 'Qualis' classifies journals by strata, according to their quality (Soares and Nova, 2016), in categories ranging from A1, A2, A3, A4, B1, B2, B3, B4, B5 and C, but does not consider impact in the same way as international journals.

Linked to this debate is the issue of collaboration between researchers worldwide. The positive aspect of global partnerships for advancing knowledge about environmental education is highlighted in this text. Tabish (2017) generally recalls the ability to conduct research in networks as a desired profile for researchers worldwide. According to Tabish, researchers from different laboratories and institutions, both national and from other countries, are collaborating more and more frequently, focusing on specific research issues (Oliveira, 2018). According to Kågström *et al.* (2023), this has become indispensable since there is a growing urgency and call for solving sustainability challenges through closer collaboration between academia and practitioners.

An initiative by To *et al.* (2019) assessed the possibilities of international collaborative research for environmental education in Asia. The authors point out that supporting the participating academic societies is crucial for conducting a large-scale survey and facilitating opportunities to increase international collaborative research skills and capacities.

For Latin America, Briggs *et al.* (2018) highlight that only a small selection of countries on this continent are represented in publications that meet the research criteria, limiting our ability to draw more solid conclusions about the region. This was attributed to deficiencies in research databases.

Our results also showed that the journals that publish the most on environmental education are those published internationally and in English. However, it is essential to note that the ranking of the most prominent journals did not consider the JCR Impact Factor. Thus, the journals with the highest local impact indexes H were Environmental Education Research, with an impact of 3.2; Journal of Environmental Education, with an impact of 3.1; and Journal of Cleaner Production, with an impact of 11.1. These journals play crucial roles in disseminating knowledge about environmental education

for young children (Novikova *et al.*, 2024), integrating indigenous and local knowledge into sustainability education (Druker-Ibáñez and Cáceres-Jensen, 2022), among others. Furthermore, the journal that occupies the top of the ranking stands out as a bimonthly international forum that promotes critical and constructive debates on various aspects of research, theory, and practice in environmental education and sustainability, consolidating itself as an essential reference in the field (Environmental Education Research, 2024).

The influence of these journals is critical to the advancement of environmental education, providing a platform for exchanging innovative ideas and sustainable practices that shape the future of educational policies and programs globally. The first periodicals were published by Taylor & Francis Online, which has witnessed exponential and rapid growth in the last two decades with the creation of publishing and distribution centers worldwide (Taylor & Francis Online, 2024).

Aligned with the essential leading journals, we highlight the principal authors by the number of articles published and the H index in the results. From the list, we highlight the role of female researchers, who comprised the majority of environmental education in this analysis. A recent study by Conceição and Teixeira (2018) demonstrates that the female presence in the international context reinforces the growing insertion of women in Science. Thus, education helps women exercise their rights and responsibilities as members of their society (Engida, 2021). This reveals that historically, the social role of women in society was unfortunately marked by a lot of prejudice and devaluation (Ferreira and Genovese, 2022).

At the top of the list, professor and director of postgraduate studies in natural resources and the environment Marianne E. Krasny has activities linked to the actions of the Civic Ecology Lab (https://www.civicecology.org/) at Cornell University. Krasny teaches a foundational course on how to scale up individual climate action through social media and social movement organizations. The researcher has also conducted online courses for audiences worldwide, including the themes of Climate Action with Family and Friends, Network Climate Action, and Environmental Education Outcomes.

In one of the most recent studies, in partnership with researcher Elena Dominguez Contreras (Contreras and Krasny, 2022), researchers explore unstructured play with young children to experience nature. The authors state that little attention has been paid to teaching efforts and learning for children about their potential to contribute

to their communities and local nature. This perspective is based on the possibility of playing with nature as environmental education. Furthermore, Professor Krasny's leading role may be associated with her research partnerships from other countries, including the Dominican Republic, Korea, Canada, and Mexico (Lee and Krasny, 2021; Contreras and Krasny, 2022).

Professor Annette Gough stood out in our research from the number of articles. Researcher Gough is an Emeritus Professor of Environmental Science and Education at the School of Education at the Royal Melbourne Institute of Technology (RMIT), in addition to having been a visiting professor at universities in Canada, South Africa, and Hong Kong (biography available at https:/ /orcid.org/0000-0002-4189-216X). Her areas of interest encompass environmental education, science education, education for sustainable development, research methodologies, feminist and postcolonial research, curriculum development, curriculum history, and educational policy studies. In one of their most recent research, Gough and Horacek (2023) teamed up with a feminist environmental cartoonist and a feminist environmental educator to explore the generativity of cartoons in environmental education research and teaching.

As for the most cited documents, we highlight the article with the highest number of citations, authored by Bamber and Möser (2007), entitled 'Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behavior,' where the authors replicate an older publication on psychosocial determinants of pro-environmental behavior. Overall, the results confirm that pro-environmental behavioral intention is mediated by the impact of all other psychosocial variables on pro-environmental behavior (27% variance explained). The results also confirm that, in addition to attitude and behavioral control, personal moral norm is a third predictor of pro-environmental behavioral intention (52% of variance explained).

Finally, we highlight the importance of niche, driving, primary, and declining topics. In the case of the niche theme, represented in the upper left quadrant, specialized topics among academics are included (Oliveira *et al.*, 2022). This result points to possible future avenues of research into environmental education, focusing on the impact of attitudes.

Among the driving topics, we identified two clusters that brought together the subjects of teaching and students with the themes of education, sustainability, and

sustainable development. This corroborates Guanio-Uluru's (2019) argument that environmental education should empower students and teachers by incorporating sustainable thinking into their teaching practices, as Lee and Krasny (2021) exemplified. This is in a context where, for the necessary development of more sustainable societies, citizens need to be supported and taught to overcome any significant gaps or challenges to being part of a sustainable society (Contreras and Krasny, 2022).

Regarding the fundamental quadrant, it was observed that the theme of knowledge, students, and conservation is at the interface with the quadrant of emerging or disappearing themes, which are simultaneously marginal and underdeveloped. The emerging or disappearing themes quadrant interfaces with the quadrant with niche themes, attitudes, environmental education, and impact. Furthermore, it is essential to highlight that the quadrant of emerging or disappearing themes has the following exclusive themes: behavior, science, and management.

The scarcity of documents on environmental fire education can be explained in several ways. According to Ryan (2012), previous experiences with forest fires can lead to more significant support for forest management techniques to reduce the danger of fire. Not all countries face fire as a direct and immediate impact on the lives of their residents. For example, Brazil, highlighted in the literature review from a bibliometric perspective, did not present any examples of projects with elementary school students on fire care. This may be related to the fact that, in Brazil, fire is more distant from people's lives, and its impact is perceived mainly in health and rural areas rather than causing significant material damage in cities. Therefore, the impact of fire may be ignored by some Brazilians, most of whom live in urban areas (Oliveira, 2021).

The analysis revealed that documents describing experiences with children and young people are more common in countries where fire represents a more serious social, economic, and environmental problem, including resulting in deaths. For example, in Portugal, as Sousa and Oliveira (2019) pointed out, the population faced traumatic experiences due to the numerous fires that occurred in the country in 2017. Portugal is one of the countries most affected by forest fires in southern Europe, with recurring events and frequent impacts, as highlighted by Santos *et al.* (2023).

In the United States of America, forest fires represent a more imminent and costly danger to the population in several areas of the country (Wall and Halvorson,

2011). For example, the wildfires in California led to the evacuation of more than 10,000 people due to 11 large fires between 2017 and 2019 (Wong *et al.*, 2020). These deadly fires result in millions of dollars in financial losses (Li *et al.*, 2024). Therefore, projects in Portugal (Sousa and Oliveira, 2019; Santos *et al.*, 2023) and the United States of America (Ballard *et al.*, 2012; Monroe *et al.*, 2016) stand out.

Due to the small number of documents describing experiences of environmental fire education in primary school, our results point to the need to include this topic in school curricula in a multidisciplinary way. We highlight the work of Ballard *et al.* (2012), which we consider fundamental for the knowledge of the school community, teachers, managers, parents, and guardians. This study highlights the importance of studying fire from different perspectives, including prevention, safety, suppression, ecology, science, and forest fire management. The authors suggest that considering the students' age group, these topics should be approached.

Furthermore, it is possible to diversify the approach to studying this topic by considering the impacts on vegetation and soils. The study by Kioupi and Arianoutsou (2016), carried out through an environmental education program for high school students, revealed significant scientific and educational value results. According to the authors, the program experience was satisfactory because students acquired essential knowledge about forest fires, soil structure and function, biogeochemistry, forest cycles, and microorganisms. Additionally, the program helped develop laboratory and communication skills and shape positive attitudes and values regarding wildfire prevention and managing wildfire-affected areas, including post-fire care of these areas.

In addition to these studies, it is worth highlighting the procedures applied in the actions of Monroe *et al.* (2016). The authors emphasize that environmental education practices should involve young people in community projects through partnerships between resource agencies, community organizations, and educators. This provides an opportunity to improve the community and educate young people through action; all partners can contribute to the common program (Monroe *et al.*, 2016).

For young children (6 and 7 years old), we highlight the action of Sousa and Oliveira (2019), who valued the (traumatic) experiences lived during the forest fires that occurred in the region of Pombal, Portugal, in 2017. The students were also continuously exposed to the approach of this topic by the media and informal

conversations in the community. A striking aspect of this study was the unprecedented use of mind maps to analyze children's perceptions.

Mind maps are low-cost resources that allow students to autonomously build their knowledge (Santos *et al.*, 2020). In addition, according to Santos *et al.* (2020), mind maps drawn by children reveal the world they live in and their experiences in space and can be used as a didactic-pedagogical resource. Thus, we highlight from Sousa and Oliveira's (2019) work the fact that the children's representations made it possible to identify, even associated with forest fires, pictorial representations of the reality close to the students, such as landscapes of forest fires in the Ervideira Lagoon, the Leiria National Forest and the Urso National Forest.

Furthermore, in the children's illustrations, representations of firefighters, aerial means, and the population fighting forest fires were identified, which were very close to the images and media content intensively disseminated on television and other regional and national media outlets (Sousa and Oliveira, 2019).

CONCLUSIONS AND RECOMMENDATIONS

The results of this research made it possible to update references on environmental education research worldwide. In addition, environmental education research focused on the study of fire was analyzed. It revealed an increase in the number of publications consolidated since the 1990s, pressured by a global scenario of awareness of the intensification of conflicts experienced by populations in various parts of the world.

We also see the leading role of female researchers from English-speaking countries, who conduct research in partnership with other researchers worldwide. These authors are involved in climate change issues, one of this analysis's central themes.

In addition to climate change, we concluded that environmental education focuses on analyzing biodiversity, waste management, and ecology. In this sense, the number of studies on environmental education is growing at 11.43%.

We also concluded that, among the total number of documents from a bibliometric perspective, only 0.152% address the topic of fire aimed at teaching in educational institutions. This suggests that the topic should be expanded, especially given its relevance, including fires in urban and rural areas and their influence on climate change. Therefore, the scant scientific production suggests a gap in the literature

and reaffirms the need for greater focus on fire management practices in the context of environmental education.

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