

## Use of ethylene-vinyl acetate in early childhood education: bibliometric overview and environmental implications

Vanessa Aguiar Lima<sup>1</sup>, Ana Cristina Aguiar de Lima da Costa<sup>1</sup>, Antonio Rodrigues da Cunha Neto<sup>1†</sup>, Alexandra dos Santos Ambrósio<sup>1</sup>, Laís da Glória Teixeira Silveira<sup>2</sup>, Carlos Henrique Zanateli<sup>3</sup>, Thais Fátima Messias Lima<sup>3</sup>, Valquíria Mikaela Rabelo<sup>4</sup>, Breno Régis Santos<sup>1</sup>

<sup>1</sup> Federal University of Alfenas: Institute of Natural Sciences; Graduate Program in Environmental Sciences; Alfenas – Minas Gerais, Brazil.

<sup>2</sup> Federal University of Lavras; Institute of Natural Sciences; Graduate Program in Applied Ecology; Lavras – Minas Gerais, Brazil.

<sup>3</sup> Federal University of Lavras; Department of Human Sciences; Graduate Program in Philosophy; Lavras – Minas Gerais, Brazil.

<sup>4</sup> Federal University of Lavras; Institute of Natural Sciences; Graduate Program in Environmental Sciences; Poços de Caldas, Minas Gerais – Brazil.

**Abstract:** Ethylene-vinyl acetate (EVA) is a copolymer whose properties can be modified by varying the amount of vinyl acetate. Among its applications, the creation of educational play materials stands out; however, improper disposal of EVA poses an environmental risk due to its potential as a pollutant. Thus, this study aimed to analyze, through bibliometric methods, the scientific discourse related to EVA and correlate the findings with a case study evaluating its use in an educational center. Initially, a bibliometric analysis was conducted using data from the last ten years, highlighting the predominance of publications in polymer and materials science, while few studies focus on the environmental and educational impacts of EVA. A case study conducted at a Municipal Center for Early Childhood Education, using Principal Component Analysis to reduce dimensionality and identify latent patterns in the data, followed by K-Means clustering for group segmentation, revealed that although many educators use EVA in educational activities, there is little awareness of its environmental impacts and inadequate disposal practices. Bibliometric analysis revealed EVA research predominantly focuses on materials science, with minimal attention to environmental and educational impacts. A case study identified three educator profiles: Cluster 1 (60%) showed high environmental awareness but inconsistent sustainable practices; Cluster 0 (18%) demonstrated high EVA dependence with low sustainability awareness; Cluster 2 (22%) exhibited moderate awareness but limited practical alternatives. It is concluded that a transition to more sustainable educational practices requires a concerted effort among educators, institutions, and policymakers, aligned with the Sustainable Development Goals.

**Keywords:** Environmental education; Scientometrics; Educational policy; Waste management.

### Introduction

Currently, plastics have become essential to human well-being and societal development, as evidenced by an approximately 23000% increase in production over the past 60 years (Geyer *et al.*, 2017; OECD, 2023). As polymers that generally have a high molecular weight, plastics take a long time to decompose, undergoing degradation through photolysis, hydrolysis, thermo-oxidation, and the action of certain microorganisms (Rhodes, 2018).

---

† Corresponding author: [antoniorodrigues.biologia@gmail.com](mailto:antoniorodrigues.biologia@gmail.com)

Manuscript received: 06/03/2025; Revised: 19/06/2025; Accepted: 24/06/2025.

Consequently, the accumulation of plastics contaminates the environment and is harmful to living organisms, as they can alter soil properties, intoxicate organisms, and emit greenhouse gases when burned (MacLeod *et al.*, 2021).

Ethylene-vinyl acetate (EVA) is a copolymer that can be modified by varying the amount of vinyl acetate in the molecule, which alters its physical and chemical properties and broadens its range of applications (Henderson, 1993). Among the various uses of EVA is the creation of educational play materials for pedagogical purposes (Coelho; Góes, 2021). However, its use poses a disposal challenge due to its potential as a pollutant.

Although recycling requires a financial investment, it is an effective method for addressing the disposal problem of EVA. However, the recycling process involves multiple stages, and its final product has a lower financial value than virgin, or new, plastic (Johansen *et al.*, 2022). According to the Organisation for Economic Co-operation and Development (OECD, 2023), only 9% of plastics worldwide are recycled, while the majority end up in landfills. Besides requiring large spaces, the degradation of this material in landfills can release greenhouse gases and microplastics into the atmosphere, which can be transported by wind to other ecosystems (Wojnowska-Baryła *et al.*, 2022).

The issue of excessive improper disposal of EVA cannot be resolved in the short term, as it requires a transformation in societal thinking and behavior, necessitating future strategies to address this problem. Additionally, more research is needed to fully understand its life cycle, mitigate the environmental damage already caused, and optimize its use (Horton, 2022). The importance of environmental education is evident for facilitating this transition to a more sustainable society, as individuals exposed to this field of knowledge during their early education tend to develop environmental awareness regarding pollution, which should be addressed in the present and reduced in the future (Soares *et al.*, 2021).

Bibliometric analysis is a fundamental statistical technique in environmental sciences, as it enables the mapping of scientific production and the identification of emerging trends, as well as the assessment of research evolution in environmental topics over time. This approach facilitates the structuring and dissemination of knowledge by quantifying the influence of authors, journals, and institutions, thereby contributing to the formulation of environmental policies and sustainable strategies. Complementary to bibliometrics, multivariate techniques such as Principal Component Analysis (PCA) offer robust tools for dimensionality reduction and pattern identification in complex datasets, enhancing the interpretation of environmental and educational variables (Hasan; Abdulazeez, 2021). In the context of waste management, climate change, and biodiversity conservation, these methods serve as an evidence-based decision-making tool, supporting the development of effective solutions (Dragos; Dragos, 2013; Si *et al.*, 2019).

As a foundation for sustainable practices, this study is grounded in the Sustainable Development Goals (SDGs) and the 2030 Agenda to build scientific thinking on the subject. Accordingly, the aim of this article is to analyze, through bibliometrics, the scientific research related to EVA and to link these findings with a case study evaluating its use in an educational center. Additionally, the study aims to assess educators' environmental perceptions regarding their pedagogical activities that utilize this material and how it is disposed of.

## Materials and methods

Initially, a bibliometric analysis on the topic was conducted, focusing on the last 10 years (2014 – 2024). The research utilized the Web of Science database, using "ethylene-vinyl acetate (EVA)" as the keyword (conducted in August 2024), allowing for discussions regarding its composition, methods of use, disposal, and potential future applications. To further discuss the results obtained from the bibliometric analysis, a case study was conducted using a qualitative approach with observational methodology (Pope; Allen, 2020) and a quantitative approach based on the application of questionnaires (Gable, 1994).

The case study was conducted at a Municipal Center for Early Childhood Education (CEMEI) located in southern Minas Gerais, Varginha, Brazil. The research received institutional approval through the Institutional Agreement Term (TAI) and the Data Use Commitment Term (TCUD), both signed by the institution's administration. This CEMEI was chosen because it is funded by the Ministry of Education through the National Program for Restructuring and Acquisition of Equipment for the Public School Network of Early Childhood Education - Pró Infância.

The sample of respondents (17 professionals) consisted of early childhood educators, distributed among the classes of Nursery I, Nursery II A and B, Kindergarten I, Kindergarten II A, B, and C, and Kindergarten III A, B, and C. The inclusion criteria included the presence of educators at the CEMEI, who were either permanent staff or contracted in 2024, in addition to signing the informed consent form.

The questionnaire developed by the authors consisted of objective questions to analyze the sample's profile and current use of EVA, as well as open-ended questions that reflected future predictions on the topic (Chart 1). The questionnaire was submitted and approved by the ethics committee, registered under the Certificate of Presentation for Ethical Consideration (CAAE) number 77989123.6.0000.5142 by the Universidade Federal de Alfenas, with prior consent from the respondents and protection of their ethical aspects through the signing of an informed consent form.

Chart 1: Questionnaire registered and approved by the CAAE used in the interviews with early childhood education professionals. (Continue)

Question	Response Type
Field of Work	Nominal categorical (4 categories)
Academic Background	Nominal categorical (3 categories)
Do you consider yourself familiar with the 2030 Agenda and the Sustainable Development Goals (SDGs)?	Binary (yes / no)
Do you consider EVA an essential resource in your pedagogical activities?	Binary (yes / no)

Chart 1: Questionnaire registered and approved by the CAAE used in the interviews with early childhood education professionals. (Continue)

Question	Response Type
Do you frequently use EVA-made pedagogical resources?	Binary (yes / no)
Do you believe it is possible to achieve pedagogical goals without using EVA?	Binary (yes / no)
Do you perceive benefits in using EVA for pedagogical practice?	Binary (yes / no)
Do you believe that EVA is a sustainable choice in your educational practices?	Binary (yes / no)
Have you considered the potential current or future environmental impacts associated with the use of EVA?	Binary (yes / no)
Have you noticed the relationship between pedagogical practice and sustainability when using EVA?	Binary (yes / no)
Do you consider that EVA disposal is not done correctly in the school environment?	Binary (yes / no)
Do you focus solely on pedagogical practice when using EVA?	Binary (yes / no)
Have you identified any alternatives to EVA that could be more sustainable from an environmental standpoint?	Binary (yes / no)

Chart 1: Questionnaire registered and approved by the CAAE used in the interviews with early childhood education professionals. (Final)

Question	Response Type
Have you ever participated in any training or workshops related to environmental education?	Binary (yes / no)
Are you familiar with the environmental legislation applicable to the disposal of materials like EVA?	Binary (yes / no)
Do you consider it important to include discussions on sustainability and environmental care in educational practice?	Binary (yes / no)
Have you developed any projects or activities that address environmental issues at school?	Binary (yes / no)
Do you understand the school environment as a suitable space to promote sustainability actions?	Binary (yes / no)
What is your perception of EVA?	Qualitative (free response)
Would you like to share any final comments that could contribute to the discussion on the topic?	Qualitative (free response)

Source: from the authors (2024).

For the analysis of word frequencies in the open-ended responses, the online tool TagCrowd was used. Initially, the responses were compiled into a single text file. This file was then uploaded to TagCrowd, where the necessary parameters were configured, such as the exclusion of common words (stopwords), setting a minimum frequency threshold for word inclusion in the word cloud, and selecting the appropriate language. Using TagCrowd, a word cloud was generated to visualize the most frequent words, allowing for a quick visual analysis of linguistic trends related to the topic (Pontes; Padilha, 2023).

Based on the responses obtained from the questionnaires, a multivariate statistical analysis was conducted. The data were normalized using the standardization technique to ensure comparability between variables. Subsequently, a Principal Component Analysis (PCA) was performed to reduce the dimensionality of the data and facilitate the visualization of underlying patterns. The K-means algorithm was then applied to identify groups of educators with similar profiles, with the optimal number of clusters determined using the Elbow Method.

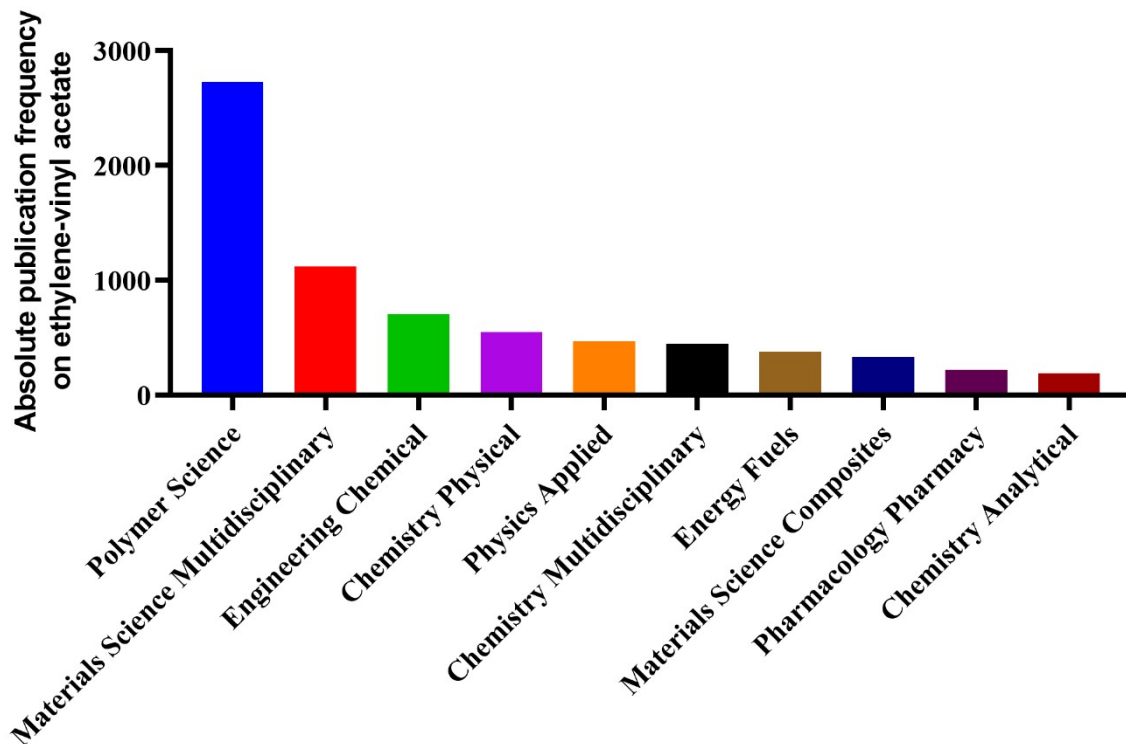
The analyses were conducted using the R statistical software (R Core Team, 2024), following the methodology outlined by Hasan and Abdulazeez (2021).

## Results and discussion

### *Bibliometric Analysis*

A search conducted using the Web of Science returned 6626 articles exploring ethylene-vinyl acetate. Research on EVA spans various fields of knowledge, including chemistry, physics, and engineering (Figure 1). As a component of numerous materials, a significant portion of the studies on EVA focuses on polymer and materials science, totaling 4180 publications.

Figure 1: Evaluation of the 10 fields of knowledge with the highest number of publications on ethylene-vinyl acetate.



Source: from the authors (2024).

A total of 2,729 articles in Polymer Science examined their physical and chemical properties, which can be modified depending on the research objectives. Other significant areas included Physical Chemistry, Applied Physics, and Materials Science, reflecting the interest in EVA's physicochemical properties and the development of novel EVA-based materials. Furthermore, its presence in categories such as Energy & Fuels and Composites suggests emerging applications in energy and composite materials. According to Henderson (1993), EVA is composed of the monomers ethylene and vinyl acetate. Manipulating the vinyl acetate content can result in variations in surface hardness, chemical resistance, compatibility with other polymers, polarity, among other properties. Additionally, combining EVA with other materials can further alter some of its properties, thereby expanding its range of applications (Kim *et al.*, 2016).

To minimize the environmental impact caused by the improper disposal of EVA, many researchers are exploring new ways to use it as a fuel. The decomposition of this polymer into its monomers can become a clean and renewable source of energy (Tai *et al.*, 2022).

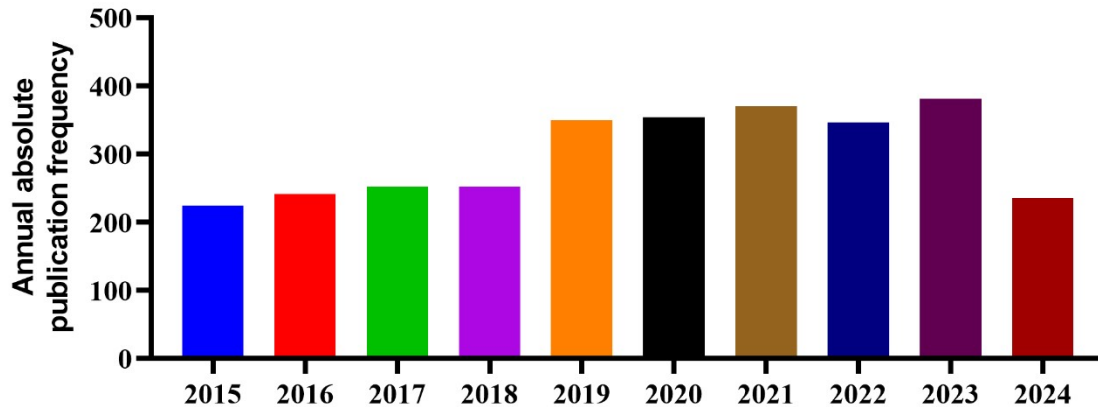
When relating EVA to environmental sciences, the bibliometric analysis identified a limited number of only 184 articles, making this field the 12th most published on this material. The analysis also found 56 articles in the field of sustainable green science technology, ranking it 36th, and only 8 articles in the field of environmental studies, placing it in the 74th position.

Although the number of studies reporting the correct disposal of EVA is minimal, several recycling alternatives exist, such as in the manufacturing of polymers (Guo *et al.*, 2019). These results also reflect a lack of research in the educational sector, despite EVA being widely used in three-dimensional models for primary education (Wijaya *et al.*, 2023), higher education (Silveira *et al.*, 2022), and inclusive education, due to its low cost, ease of manipulation, and soft texture (Ruiz-Sanchez *et al.*, 2019).

Based on the data presented in Figure 1, one can reflect on the scarcity of studies on EVA within the educational context. Its use may not significantly promote the development of new teaching methodologies in basic education, as some schools have the infrastructure to purchase technological tools and enhance learning. Alternatively, the value of three-dimensional models that can be used for teaching, such as those created by 3D printers, might have decreased. The natural degradation of EVA present in schools can release plastic microparticles into the atmosphere, which may be harmful to the human body, reinforcing the need for studies on the residual impact of EVA in schools (Le *et al.*, 2023).

In line with technological advancements, there has been a general increase in publications related to EVA over the past decade (Figure 2). Constant innovations in medicine and industrial procedures are reflected in the number of publications since 2019. It is notable that, despite this increase, the amount of research related to education, particularly environmental education, remains scarce.

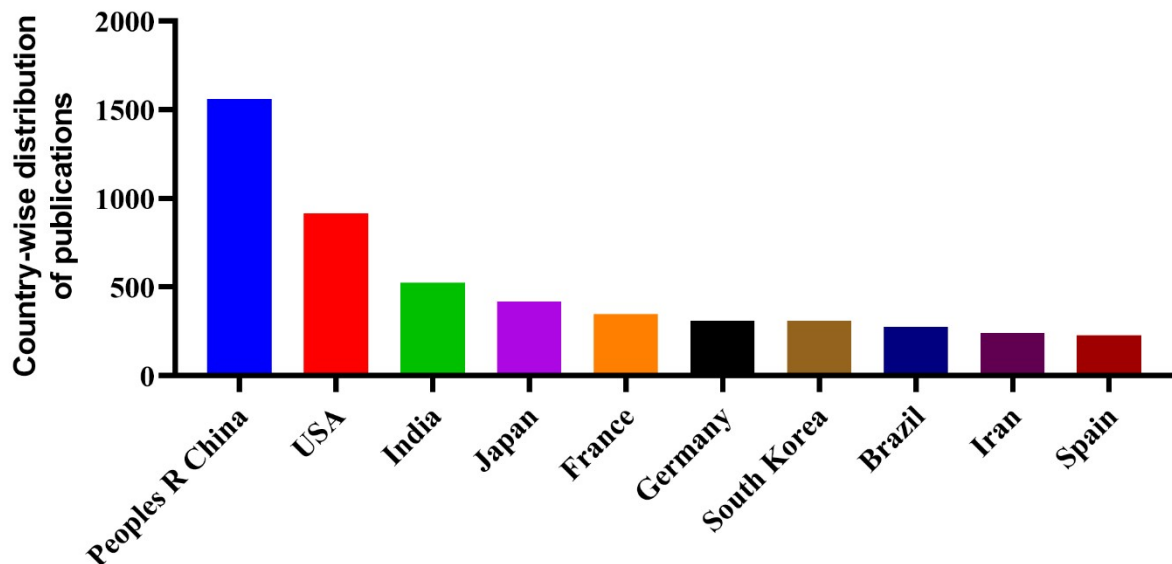
Figure 2: Number of publications per year on ethylene-vinyl acetate.



Source: from the authors (2024).

Asian countries are at the top of the ranking with EVA publications (2634), with China contributing more than 50% of this total (Figure 3). Following are the United States with 915 publications, European countries with 884, and Brazil with 276. Individually, Brazil ranks 8th among the countries with the most publications related to EVA. In none of the cited countries or regions was it possible to observe a focus on publications about the disposal of EVA and the environmental damage it may cause.

Figure 3: Countries with the most publications on ethylene-vinyl acetate.



Source: from the authors (2024).

In reverse order to the data shown in Figure 3, the countries that polluted the oceans the most with plastics in 2019 were, respectively: Malaysia, Brazil, India, and China (Pariatamby *et al.*, 2020). The number of publications on the material does not reflect the sustainability of a nation regarding waste production and disposal. According to Brazilian Federal Law No. 12,305/2010,

which establishes the National Solid Waste Policy (PNRS), Article 10, §1 states: "Os geradores de resíduos sólidos, incluindo os que operam com produtos recicláveis ou reutilizáveis, devem gerenciar seus resíduos de forma ambientalmente adequada" ("Solid waste generators, including those operating with recyclable or reusable products, must manage their waste in an environmentally appropriate manner" - our translation from the original Portuguese). This legal provision requires Brazilian institutions to implement proper EVA waste management through recycling or repurposing processes.

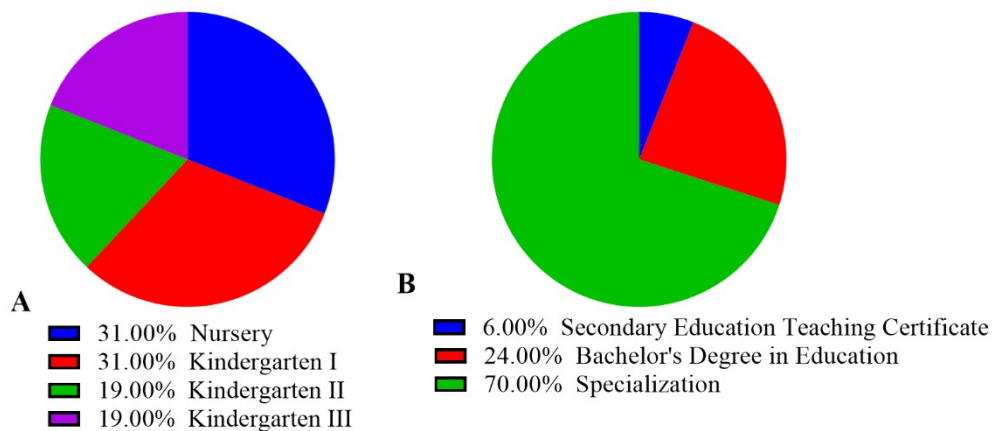
In the Brazilian institutional context, the management of plastic waste, such as EVA, should be integrated into each institution's solid waste management plan. The PNRS, in its Article 9, advises that "selective collection systems should be structured to ensure efficiency and effectiveness in the separation of recyclable and non-recyclable materials".

Although Brazilian legislation strongly encourages the recycling and reuse of plastic products like EVA, the PNRS establishes specific reverse logistics requirements in Article 33: "Os fabricantes, importadores, distribuidores e comerciantes de produtos que gerem resíduos sólidos devem estruturar e implementar sistemas de logística reversa, independentemente dos serviços públicos de limpeza urbana e de manejo de resíduos sólidos" ("Manufacturers, importers, distributors, and retailers of products that generate solid waste must establish and implement reverse logistics systems, regardless of the public urban cleaning and solid waste management services" - our translation from the original Portuguese). This legal framework mandates active waste management engagement through partnerships with material suppliers to promote EVA return and recycling programs.

### ***Case Study - Municipal Center for Early Childhood Education (CEMEI)***

Among 17 professionals interviewed at the CEMEI, 31% (5 professionals) worked in nursery classes versus 69% (11 professionals) in early childhood education (Figure 4A). Over 90% (16 professionals) had university degrees, including 70% with postgraduate specializations (Figure 4B).

Figure 4: (A) Area of work and (B) academic background of professionals working at the municipal center for early childhood education.



Source: from the authors (2024).

Table 1 presents the questionnaire analysis results, revealing a contradiction between environmental awareness and pedagogical practices among interviewed professionals. Although 100% (17 professionals) of respondents reported familiarity with the 2030 Agenda and acknowledged the importance of incorporating sustainability into their practice, only 12% (2 professionals) considered the environmental impacts of EVA, and none demonstrated knowledge of proper disposal regulations. Despite 94% (16 professionals) frequently using EVA-based teaching materials, 76% (13 professionals) failed to recognize the connection between their usage and sustainability. All respondents acknowledged inadequate EVA disposal practices at their school, while 60% (10 professionals) had identified more sustainable alternatives.

Table 1: Frequency distribution of responses on EVA use, sustainability awareness, and disposal practices among early childhood educators (n = 17). (Continue)

	Yes	No	Did not respond
Are you familiar with the 2030 Agenda and the Sustainable Development Goals (SDGs)	100%	0%	0%
Do you consider EVA an essential resource in your pedagogical activities?	34%	60%	6%
Do you frequently use pedagogical materials made with EVA foam?	94%	6%	0%
Do you believe it is possible to achieve pedagogical objectives without using EVA?	70%	30%	0%
Do you perceive benefits in using EVA for pedagogical practice?	82%	12%	6%
Do you believe that EVA is a sustainable choice in your educational practices?	70%	18%	12%
Have you considered the potential current or future environmental impacts associated with the use of EVA?	12%	76%	12%
Have you noticed the relationship between pedagogical practice and sustainability when using EVA?	18%	76%	6%
Do you believe that the disposal of EVA is not done properly in the school environment?	100%	0%	0%
Do you limit your thinking to only the pedagogical practice when using EVA?	94%	6%	0%
Have you identified alternatives to the use of EVA that might be more environmentally sustainable?	59%	35%	6%
Have you ever participated in any training or professional development related to environmental education?	82%	18%	0%
Are you familiar with the environmental legislation applicable to the disposal of materials like EVA?	24%	0%	76%

Table 1: Frequency distribution of responses on EVA use, sustainability awareness, and disposal practices among early childhood educators (n = 17). (Final)

	Yes	No	Did not respond
Do you consider it important to include discussions about sustainability and environmental care in educational practice?	100%	0%	0%
Have you ever developed projects or activities that address environmental issues in the school?	100%	0%	0%
Do you understand the school environment as a suitable space for promoting sustainability actions?	100%	0%	0%

Source: from the authors (2024).

According to the National Solid Waste Policy (PNRS), each state and municipality must develop a plan for the management and handling of solid waste (BRASIL, 2010). The state legislation of Minas Gerais, represented by Law No. 14128/2001, reinforces this guideline by establishing a State Policy for Material Recycling. Article 2, item IV, of this law states that it is the responsibility of the Executive Branch to “promote environmental education campaigns aimed at disseminating and valuing the use of recyclable materials and their benefits.” Schools, as educational environments, play a significant role in implementing these campaigns by integrating them into the school curriculum and raising awareness among students and staff about the importance of proper disposal and recycling practices for materials such as EVA.

Analyzing the respondents answers using the online tool TagCrowd, the words “durability”, “recycling”, and “substitution” stood out (Figure 5). The teachers are aware of the durability of EVA, which is an attractive property of the material and a reason for their resistance to replacing it with another product. There is a noted need for courses or seminars that present new ideas and stimulate the creativity of professionals to adapt their teaching materials in favor of sustainability, where natural elements could be used as a substitute for EVA.

Figure 5: Word cloud showing the frequency of the most commonly used words in open-ended responses.



Source: from the authors (2024).

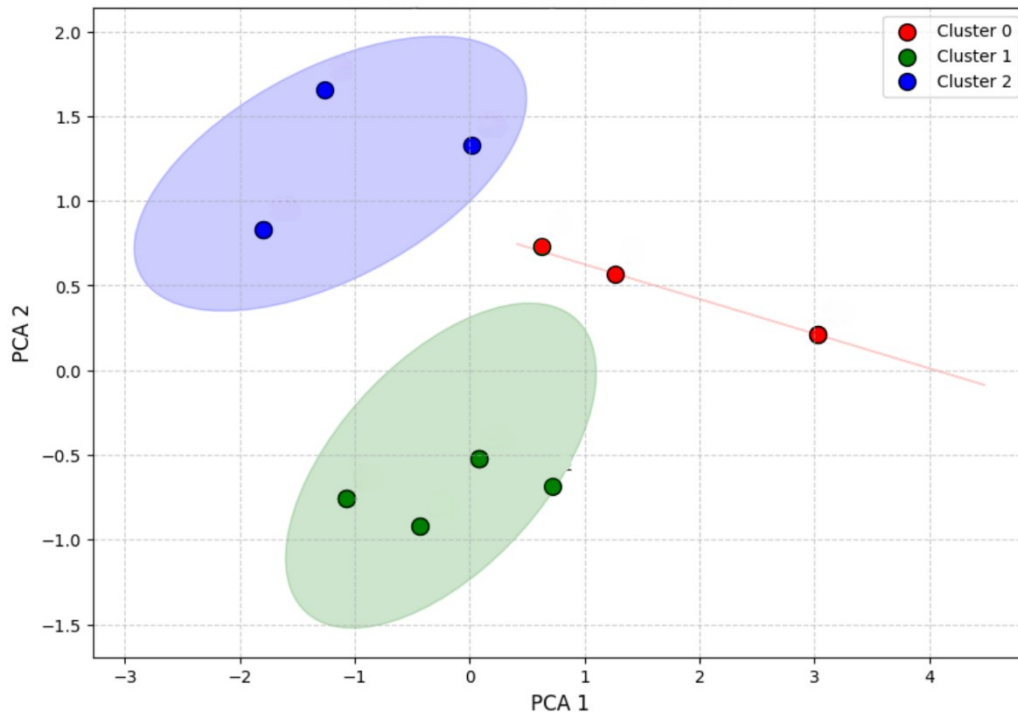
As established in Minas Gerais State Law No. 14,128/2001, Article 4-A: "Art. 4º-A. Fomentar alternativas de crédito ou incentivos financeiros a indústrias e instituições que se disponham a trabalhar com produtos reciclados ou a fabricar novos produtos ou matérias-primas a partir de materiais reciclados" ("Art. 4-A. To promote credit alternatives or financial incentives for industries and institutions willing to work with recycled products or to manufacture new products or raw materials from recycled materials" - our translation from the original Portuguese). This legal framework supports schools in adopting alternatives to EVA, such as biodegradable or recycled materials, to reduce environmental impact.

The educators perception of the importance of discussing sustainability in educational practice reveals a gap between this perception and the environmental reality, indicating the need for a more integrated approach to environmental education in practice. There is an understanding of the importance of practicing and promoting recycling, even if the school is not currently acting in this manner.

Environmental education plays a fundamental role in changing behavior and promoting sustainable practices within the school environment. The National Solid Waste Policy (PNRS - Law No. 12,305/2010) highlights the fundamental role of environmental education, as established in its Article 7: "Art. 7º. Promover a educação ambiental [...] para a conscientização sobre a necessidade de reciclagem e de gestão sustentável de resíduos" ("Art. 7. To promote environmental education [...] to raise awareness about the need for recycling and sustainable waste management" - our translation from the original Portuguese). Schools should integrate these concepts into their curriculum by promoting workshops, lectures, and practical activities that demonstrate the consequences of the improper use of plastics and the importance of recycling.

Principal Component Analysis (PCA) was applied to reduce the dimensionality of the data and facilitate the visualization of the underlying structure of the analyzed variables. The resulting biplot (Figure 6) illustrates the distribution of the clusters identified by the K-Means clustering method, highlighting three distinct profiles of educators regarding EVA usage and their sustainable practices. The first principal component (PCA1) is strongly associated with the perception of EVA usage, while the second principal component (PCA2) reflects participants' environmental awareness. The arrows representing the original variables indicate the correlation of these dimensions with the principal components, showing that individuals with greater awareness of environmental impacts and sustainable practices tend to cluster differently from those with a less critical view of EVA usage. This separation suggests that environmental awareness plays a significant role in adopting more sustainable practices within the educational environment, reinforcing the need for training initiatives focused on sustainability and the proper disposal of pedagogical materials.

Figure 6: Biplot of the Principal Component Analysis (PCA) representing the distribution of clusters formed based on the variables: perception of EVA usage, awareness of environmental impact, and sustainable practices.



Source: from the authors (2024).

Legend: The colored points indicate individuals grouped into three distinct clusters according to the K-Means clustering analysis. The red arrows represent the original variables, indicating the direction and intensity of their influence on the principal components. The PCA1 axis primarily reflects the perception of EVA usage, while the PCA2 axis highlights educators' environmental awareness.

When profiling the respondents, they were grouped into three categories. The first group is characterized by professionals with a high perception of EVA use, low environmental awareness, and low sustainable practices, comprising only 18% (3 professionals) of the respondents. The second group, which contains the largest percentage of respondents (60%, 10 professionals), consists of professionals with an intermediate perception of EVA use, high environmental awareness, and high sustainable practices. The last group (22%, 4 professionals) is composed of professionals with a low perception of EVA use, high environmental awareness, and intermediate sustainable practices.

The analysis of educators' profiles reveals a significant discrepancy between awareness of sustainability and the practical implementation of sustainable actions in schools, particularly in the proper management of EVA. This gap highlights the need for a more integrated approach to environmental education that not only informs but also empowers both students and educators to adopt daily practices that reflect environmental awareness. Strengthening the training of educators and incorporating practical activities into the school curriculum can be crucial for transforming environmental awareness into concrete actions, promoting a culture of sustainability that benefits the school environment and the community (Ardoin and Bowers, 2020).

## Conclusion

The publication of articles on ethylene-vinyl acetate (EVA) has significantly increased in volume since 2019. However, there are few articles focused on the use of EVA in educational contexts and environmental studies. The analysis of respondents' profiles reveals a significant diversity of perceptions and practices related to the use of EVA, environmental awareness in the educational context, and the management of this material. For schools to properly dispose of EVA used in pedagogical play activities, it is essential to follow the guidelines established by both federal and state legislation. The adoption of selective collection practices, partnerships with recyclers, promotion of environmental education, and the use of more sustainable alternatives are essential future actions to minimize the environmental impact of these materials. Bibliometric analysis is essential for decision-making as it allows for the identification of patterns in data and the assessment of trends in environmental practices. Principal Component Analysis (PCA) and K-Means clustering enabled the classification of educators into different profiles. This quantitative approach was fundamental in supporting data analysis, ensuring that sustainability-oriented actions are implemented based on evidence, removing the subjectivity often found in studies that rely on questionnaire-based methodologies.

## Acknowledgements

The authors would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) [Funding Code 001], CAPES/BRASIL PDPG-POSDOC No. 2930/2022, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) for their financial support and research scholarships.

## Conflicts of interest and the use of artificial intelligence

There are no conflicts of interest.

## References

- ARDOIN, Nicole M.; BOWERS, Alison W. Early childhood environmental education: A systematic review of the research literature. **Educational Research Review**, v. 31, p. 100353, 2020. DOI: 10.1016/j.edurev.2020.100353.
- BRASIL. Lei nº 12.305, de 2 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos; altera a Lei nº 9.605, de 12 de fevereiro de 1998; e dá outras providências. **Diário Oficial da União**, Brasília, DF, 3 ago. 2010. Disponível em: [http://www.planalto.gov.br/ccivil\\_03/\\_ato2007-2010/2010/lei/112305.htm](http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/112305.htm). Acesso em: 03/2025.
- COELHO, J. R. D.; GÓES, A. R. T. Geometria e Desenho universal para aprendizagem: uma revisão bibliográfica na Educação Matemática inclusiva. **Educação Matemática Debate**, v. 5, n. 11, p. 1-26, 2021. DOI: 10.46551/emd.e202122.

DRAGOS, C. M.; DRAGOS, S. L. Bibliometric approach of factors affecting scientific productivity in environmental sciences and ecology. **Science of the Total Environment**, v. 449, p. 184-188, 2013. DOI: 10.1016/j.scitotenv.2013.01.057.

GABLE, Guy G. Integrating case study and survey research methods: an example in information systems. **European Journal of Information Systems**, v. 3, n. 2, p. 112-126, 1994. DOI: 10.1057/ejis.1994.12.

GEYER, Roland; JAMBECK, Jenna R.; LAW, Kara L. Production, use, and fate of all plastics ever made. **Science Advances**, v. 3, n. 7, e1700782, 2017. DOI: 10.1126/sciadv.1700782.

GUO, Hongwei; YUE, Lei; RUI, Gao; MANAS-ZLOCZOWER, Ica. Recycling poly (ethylene-vinyl acetate) with improved properties through dynamic cross-linking. **Macromolecules**, v. 53, n. 1, p. 458-464, 2019. DOI: 10.1177/08927057221095388.

HASAN, Bayan M. S.; ABDULAZEEZ, Ammar M. A review of principal component analysis algorithm for dimensionality reduction. **Journal of Soft Computing and Data Mining**, v. 2, n. 1, p. 20-30, 2021. DOI: 10.30880/jscdm.2021.02.01.003.

HENDERSON, Alan M. Ethylene-vinyl acetate (EVA) copolymers: a general review. **IEEE Electrical Insulation Magazine**, v. 9, n. 1, p. 30-38, 1993. DOI: 10.1109/57.249923.

HORTON, Alice A. Plastic pollution: When do we know enough?. **Journal of Hazardous Materials**, v. 422, p. 126885, 2022. DOI: 10.1016/j.jhazmat.2021.126885.

JOHANSEN, M. R.; CHRISTENSEN, T. B.; RAMOS, T. M.; SYBERG, K. A review of the plastic value chain from a circular economy perspective. **Journal of Environmental Management**, v. 302, p. 113975, 2022. DOI: 10.1016/j.jenvman.2021.113975.

KIM, J.; SEUNGWON, L.; BYOUNG, C. K.; BONG-SEOB, S.; JONG-YOUNG, J.; CHAE, D. W. Effect of VA and MWNT contents on the rheological and physical properties of EVA. **Korea-Australia Rheology Journal**, v. 28, n. 1, p. 41-49, 2016. DOI: 10.1007/s13367-016-0004-9.

LE, V. G. *et al.* A comprehensive review of micro-and nano-plastics in the atmosphere: Occurrence, fate, toxicity, and strategies for risk reduction. **Science of The Total Environment**, p. 166649, 2023. DOI: 10.1016/j.scitotenv.2023.166649.

MACLEOD, M.; ARP, H. P. H.; TEKMAN, M. B.; JAHNKE, A. The global threat from plastic pollution. **Science**, v. 373, n. 6550, p. 61-65, 2021. DOI: 10.1126/science.abg5433.

MINAS GERAIS. Lei nº 14.128, de 19 de dezembro de 2001. Dispõe sobre a política estadual de reciclagem de materiais e sobre os instrumentos econômicos e financeiros aplicáveis à gestão de resíduos sólidos. **Diário do Executivo**, Minas Gerais, 20 dez. 2001. Disponível em: <https://www.almg.gov.br/consulte/legislacao/leis/L14128.html>. Acesso em: 03/2025.

OECD. Global Plastics Outlook - Plastics waste by region and end-of-life fate. 2023. Disponível em: <https://ourworldindata.org/grapher/share-plastic-fate>. Acesso em: 03/2025.

PARIATAMBY, A. *et al.* Status of microplastic pollution in aquatic ecosystem with a case study on Cherating River, Malaysia. **Journal of Engineering and Technological Sciences**, v. 52, n. 2, p. 222-241, 2020. DOI: 10.5614/j.eng.technol.sci.2020.52.2.7.

R CORE TEAM. R: A Language and Environment for Statistical Computing. Vienna, Austria: **R Foundation for Statistical Computing**, 2024. Disponível em: <https://www.R-project.org/>. Acesso em 06/2025.

RHODES, C. J. Plastic pollution and potential solutions. **Science Progress**, v. 101, n. 3, p. 207-260, 2018. DOI: 10.3184/003685018X15294876706211.

SI, H.; SHI, J. G.; TANG, D.; WEN, S.; MIAO, W.; DUAN, K. Application of the theory of planned behavior in environmental science: a comprehensive bibliometric analysis. **International Journal of Environmental Research and Public Health**, v. 16, n. 15, p. 2788, 2019. DOI: 10.3390/ijerph16152788.

SILVEIRA, B. W. M. *et al.* Assembly and use of a low-cost paracentesis simulator for the teaching of puncture and drainage of ascites. **Revista do Colégio Brasileiro de Cirurgiões**, v. 49, p. e20223099, 2022. DOI: 10.1590/0100-6991e-20223099.