

Special Issue
Engineering the Future Sociologically:
a Call to Delve into Environmental
Education Enhanced by
Technological Innovations

FUORI LUOGO

**Journal of Sociology of Territory,
Tourism, Technology**

Guest Editors

Norberto Albano
Sandro Brignone
Carmine Urciuoli



Editor in Chief: Fabio Corbisiero
Managing Editor: Carmine Urciuoli

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Mapping Technology Usage in Environmental Education²

Introduction

The future of the planet faces significant challenges, including climate change, global warming, exhaustion of natural resources, desertification, and others (Grosbeck *et al.*, 2019), with countries worldwide having shown increasing interest in environmental issues (Jickling & Wals, 2012). One of the key instruments for ensuring a better future for both people and the planet is Environmental Education (EE). This realization came as early as 1987, as the World Commission on Environment and Development established the Brundtland Commission with the goal of raising awareness among nations regarding sustainable development issues. Such awareness was intended to be fostered through extensive educational campaigns (Yang & Xiu, 2023).

However, at the time, said document was not taken seriously as the global community did not yet recognize the importance of EE (Lambrechts & Hindson, 2016). The turning point came a few years later, in 1992, with the release of Agenda 21, in which the UN acknowledged the central role of education in environmental matters, and, since then, EE activities have been increasingly established (Yang & Xiu, 2023). It is important to recognize that EE extends beyond primary and secondary levels to also include tertiary education (Trencher *et al.*, 2014) as well as lifelong learning: tertiary education makes significant contributions that are often overlooked; higher education institutions are seen as responsible for training future teachers (*ibid.*; Hallinger & Chatpin-yakoo, 2019); EE is also discussed outside institutional education, in respect to lifelong learning, reskilling, and other areas (Gough, Walker, & Scott, 2001; Ardoin & Heimlich, 2021).

There are various methods of implementing EE, the most common being problem-solving: teachers present students with real problems, engaging them in finding solutions (Reese, 2019). This approach may allow students to critically reflect on their own learning and provide them with opportunities to shape their education in a meaningful way. (Wals, 1994, p. 2). Another approach is through outdoor activities, such as physical exercises, nature walks, and excursions, which allow students to connect with the environment more than classroom settings can (Maidatsi *et al.*, 2022). These approaches are often combined: students leave the classroom to encounter real-world problems, supposedly leading to better performances (Yıldırım & Akamca, 2017). Other projects integrate EE into the teaching of natural sciences (Garner *et al.*, 2018). This more formal educational method suffers from the frequent lack of textbook sections dedicated to the topic and limited curricular time (Maidatsi, 2022, *op. cit.*).

Technologies can be valuable tools for EE and Education for Sustainable Development (ESD), allowing people to access necessary information in immediate and diverse ways to increase environmental awareness. Some scholars argue that UNESCO should promote EE in conjunction with technology; this potential has not yet been fully exploited (Yang & Xiu, 2023). Empirical investigations are needed to understand how technology can be used in EE (Albareda-Tiana *et al.*, 2018; Badea *et al.*, 2020).

Such enquiries should bear relevance to social factors beyond the pedagogical or technical implications of technology. Attitudes toward digital tools (Masrom, 2007) and the digital divide (Hargittai, 2003) can significantly shape how these technologies are implemented and who benefits from them. We can conceptualize the digital divide considering both the physical access to technological resources and access to related resources like time, social capital, cognitive and mental capacities, emotional resources. (Hargittai, 2001). Indeed, while digital innovations have the potential to democratize education, they may also reinforce existing inequalities if access to digital infrastructure and technological literacy is unevenly distributed (Sriprakash *et al.*, 2024).

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Given the various proposals for technology usage in education, and EE specifically, and considering numerous integrations of disruptive technologies in educational practices, the goal of this work is to investigate the purposes for which ICT is used in EE. Exploring academic literature on the topic can help clarify the relationship between technologies and educational practices, its evolution over time and its progressive diffusion and sophistication, serving as a starting point for broader sociological reflections on the relationship between technology, EE and digital inequalities.

While it is important to specify that this article will refer to EE and not to ESD, the distinction between EE and ESD is debated: according to some authors, EE and ESD are commonly depicted as either interconnected concepts or separate ideologies, depending on the focus placed on a human-centered viewpoint (Briggs *et al.*, 2018). In this work, the authors conceive EE as the overarching theme of which ESD is a subset (Cartea, 2005). For similar reasons, we focus on Information and Communication Technology (ICT) in this work due to the breadth of its definition, encompassing both analog and digital technologies (UNESCO, 2018) and providing grounds for an exhaustive classification.

1. Taxonomies in Education, Technology and EE

When it comes to taxonomies, EE can rely on the important contribution of Bloom's Taxonomy and its revised versions. It originally categorized educational objectives into six hierarchical levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Bloom *et al.*, 1956). In the 1990s, a revision led by Lorin Anderson transformed these into action-oriented verbs: Remember, Understand, Apply, Analyze, Evaluate, and Create, with "Create" at the pinnacle to emphasize its importance (Anderson & Krathwohl, 2001). Bloom's Taxonomy has left a legacy, providing guidance for educators to design curricula fostering critical thinking and problem-solving skills. Its revised version also shifted the focus to specific practices, inspiring many classifications in the discipline.

A first taxonomy of the uses of digital technologies in the educational field comes from Bruce (1991) who, focusing on personal computers, theorized their use as: teachers, capable of identifying, personalizing and monitoring learning; tools to support the reading, production and storage of texts; means for exploring language; media, as vectors of hypertextual and multimedia content; communication environments serving students and teachers. Another typology (Mama & Hennessy, 2013) focuses on the combinations of teachers' beliefs and practices regarding the use of ICT, identifying 4 types of uses: integrative, the use of technologies aimed at diversifying the approaches and needs of individual students; incremental, aimed at supporting and improving existing practices; incidental, limited mostly to administrative tasks; inimical, avoided and viewed with suspicion. This subdivision highlights the advantages that technologies may provide through their implementation. Some scholars argue that integrating new technologies into rigid, existing educational programs and consolidated models can hamper their potential benefits because of the limiting procedures already in place (Flavin, 2017). While this can be the case in numerous scenarios, technology happens to situate itself into many complex relationships. Tapia Cortes (2020), based on their review of existing taxonomies to which we refer for completeness, creates their own typology of technology usage: as a means of communication, social and personal use, as a cultural component (mediation of interaction between human actors), managerial and administrative use, instrumental use.

Focusing on digital technologies, their areas of application in education are numerous, including: development, dissemination and access to online content; distance learning; support for students with physical or learning difficulties; collaborative virtual environments; promotion of students' independent learning; sharing and rapid updating of information; multimedia teach-

ing; increase in sources of learning; environmental benefits; real-time student assessment (Haleem *et al.*, 2022). Less frequent in the literature are explicit, systematic mentions of the specific technologies at play. An important reference to new technologies can be found in the UNESCO ICT Competence Framework, a document aimed at teachers and professionals, that lists relevant emerging technologies for education, such as Open Educational Resources (OER), social networks, mobile technologies, the Internet of Things (IoT), Artificial Intelligence (AI), virtual reality (VR) and augmented reality (AR), Big Data (UNESCO, 2018).

Additionally, there are several bibliometric works focusing on EE and ESD which show that the disciplines have expanded significantly only from 2004 onward, and that the growth rate has increased even more after 2015 (Yang & Xiu, 2023; Grosseck *et al.*, 2019; Chang *et al.*, 2021). In noting so, innovation in education technology has been detected as a significant discipline in the field. As of now, there are no scoping reviews focused on technology usage in EE, and we aim to propose a taxonomy to describe it, drawing from existing ones in education technology.

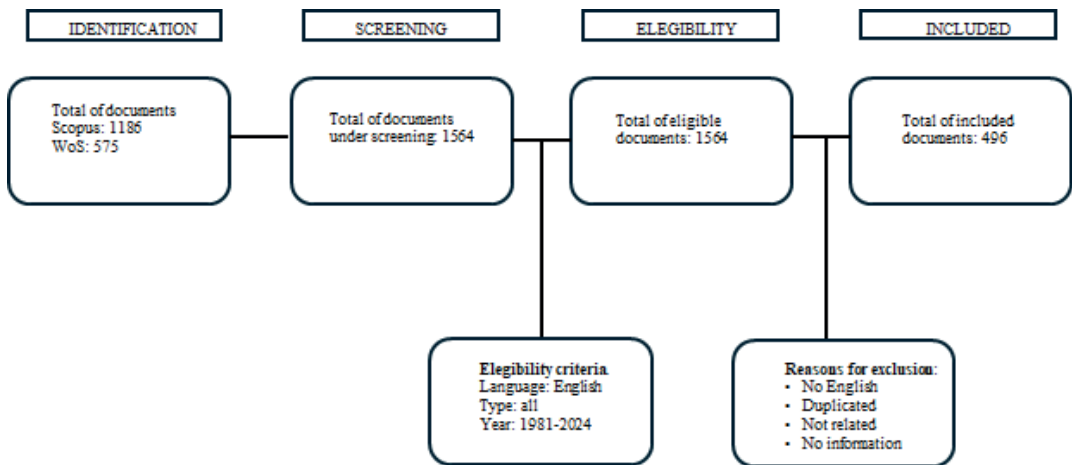
2. Methods

Our research question can be formalized as follows: what are the main usages, objectives and participants of ICT usage according to the state of the art in EE?

To address this question, a two-phase approach called the bibliometric-textual procedure was employed. This involved incorporating reliable methods of bibliometric analysis through the PRISMA method along with Latent Dirichlet allocation (LDA), an automated textual analysis technique. Bibliometric analysis is described as a widely used and systematic approach for examining and analyzing extensive scientific data. Its widespread use is attributed to factors such as the progress, availability, and accessibility of bibliometric software and databases like Scopus and Web of Science, as well as the interdisciplinary influence of bibliometric methods (Mukherjee *et al.*, 2021, p. 1). Bibliometrics provides in-depth analyses of the body of scientific publications on a topic using various tools, synthesizing the state of the art in a particular area of study, and identifying emerging research priorities (Page *et al.*, 2021). As suggested by Fan *et al.* (2022), a descriptive analysis of a theme or research field, even if conducted rigorously and comprehensively, should be developed in a way that provides a foundation for conceptual and theoretical advancements on the subject.

To avoid redundancy in one's work with respect to existing literature, it is necessary to (1) define a clear research objective and (2) supplement classic bibliometric measures with other analytical techniques. The risk is producing a work that lacks depth, hence the need for more complex research designs (Maraolo, 2021; Ellegaard & Wallin, 2015). The bibliometric analysis process involves four key steps: 1. Define the objectives and scope; 2. Select the techniques; 3. Gather the data; 4. Perform the bibliometric analysis and present the results (Donthu *et al.*, 2021). The third step is the most delicate in bibliometric research as it underpins transparency and replicability, key elements of good research (Freese & Peterson, 2017). For this reason, PRISMA, an acronym for "Preferred Reporting Items for Systematic Reviews and Meta-Analyses," was defined as a reporting guideline aimed at improving the quality of reporting in systematic reviews (Liberati *et al.*, 2009). It is comprised of a checklist of 27 items providing recommendations for conducting transparent and replicable research (Page *et al.*, 2021, *op. cit.*). PRISMA is often accompanied by a flow-chart (Figure 1), graphically describing key points of the collection process: screening, selection, and inclusion of articles.

Figure 1. PRISMA flowchart



Supplementing bibliometric analysis with textual analysis techniques can fill its gaps and enrich the results (Glenisson et al., 2005). This approach is especially effective when working with a limited number of scientific articles. (Blei et al., 2003; Glänzel et al., 2017).

The technique allows the discovery of underlying themes in a collection of unstructured documents. The idea is that within the corpus there are various topics, and topic modeling can identify them by pinpointing the most representative words for each theme (Veltri, 2021, pp. 163-165). In this work, the identification of keywords for each theme enabled the structuring of a typology. The dataset was constructed on 18/03/2024 using data export tools from Scopus and WoS. Both databases were used because most research on the topic has been conducted on one or the other to exploit their specific capabilities (Yang & Xiu, 2023, op. cit.). It is often suggested to use both databases simultaneously since they are complementary (Sánchez et al., 2017). Google Scholar was not considered because, although it has better coverage across all disciplines, most statistical sources and materials are of unknown origin (Leydesdorff et al., 2016), and it provides records that are not easily compatible with the databases already considered. The collection queries were:

- For Scopus: TITLE-ABS-KEY ("environmental education") AND ("technology*")
- For WoS: TOPIC1 ("environmental education") AND ("technology*")

The decision to use "technology"* rather than "technolog"* was motivated by the need to optimize the relevance and precision of the dataset after careful testing of the retrieval procedure. The broader truncation "technolog*" would have significantly increased the number of retrieved results, incorporating a substantial proportion of less relevant studies. Specifically, it would have expanded the dataset to include terms such as technological and technologist, the latter shifting the focus toward professional roles associated with technology rather than the technological domain itself. Moreover, this broader truncation would have automatically encompassed all terms prefixed with technology, such as technology-driven and technology transfer, which do not directly pertain to the research scope. Consequently, the selection of "technology"* was guided by the necessity to maintain an appropriate balance between recall and precision, mitigating excessive dataset expansion with extraneous documents and minimizing noise in the retrieved data, while acknowledging the potential for a slight underestimation compared to a more exhaustive manual expansion.

No time limits were imposed. Only articles in English across all disciplines were selected. A total of 1564 articles were collected. This number was reduced after cleaning operations, which involved manual checking of article titles and abstracts to identify those truly focused on the topic, eliminating duplicates, and removing records with missing information. The final number of articles in the dataset was 496. This number is sufficient to justify bibliometric analysis for this collection (Donthu *et al.*, 2021).

The bibliometric analysis was carried out using Bibliometrix, a package providing a range of tools for quantitative bibliometric research. Written in the R language, it features the user-friendly Biblioshiny interface. Bibliometrix is considered a robust and versatile tool, capable of performing optimally even when analyzing datasets constructed from different databases, as in this work (Aria & Cuccurullo, 2017; Arruda *et al.*, 2022).

LDA was conducted using T-Lab, a specialized software for textual analysis that includes linguistic, statistical, and graphical tools for multidimensional analysis. Much of the data preprocessing was automated through T-Lab's tools. The only exceptions were the removal of some words not recognized by the software as stop-words and the lemmatization of certain words.

3. Results

3.1. Bibliometrics

The collection, including all document types in the data banks, goes from 1981 to 2024 and has an annual growth rate of 5.95%, several times lower than the growth rate of ESD. However, following a long period of scarce, occasional publications, the collection highlighted an increased production from 2017 onward, aligning with findings from broader bibliometric analyses (Dönmez, 2024). The timespan can be divided into two phases, the first one (1981-2017) characterized by slow and erratic increases in production and the second one (2017-2024) characterized by a more pronounced but still variable growth rate. Further analysing the first phase, some spikes in production can be identified: in the period 1996-1997, due to a growing number of proposals for GIS (Witham Bednarz, 2004) and satellite imagery (Goto, 2002) usage in EE, supported by a booming internet industry (Castells, 2001) and expanding multimedia applications; in the period between 2009 and 2011 these ICTs are still being frequently implemented, and a new interest on e-learning and VR is found. At this point the focus is shifting towards the seamless integration of said technologies into teaching practices and curricula (Fan *et al.*, 2010). During the second phase (2017-2024) mobile learning, AR, IoT and AI emerge as relevant technologies in the field, while integration into learning programs and teaching practices is much more frequent.

The most relevant sources in the collection are the "E3s Web of Conferences" and the Journals "Sustainability", "Journal of Environmental Protection and Ecology" and "Journal of Environmental Education". This shows affinity with EE's sources ecosystem, as well as an interest in open publishing. However, calculating the Bradford's Law (Bradford, 1934) zones for this collection shows a high number of sources in the core zone (53 out of 384) and the middle zone (160 of 384), meaning that the coverage is distributed across a wide number of sources with low productivity. This finding is expected when dealing with very broad topics (like ICTs) and is consolidated by similar results when applying Lotka's Law to the collection: the share of occasional authors (with only 1 article in the collection) is 93.7% of the total, a pattern which suggests a diverse and fragmented field with low centralization of research activities.

Textual analysis on the authors' keywords, when expunging less informative words like query synonyms and disciplines, provides a first glance at the technologies involved in EE (Figure 2). It also shows how these technologies are employed as means to several objectives and different targets.

- locations. The main participants of these activities are primary or lower secondary school students. These technologies enable individuals, including those with disabilities or mobility issues, to experience and understand the natural environment through digital representation.
- Clean energy through multimedia. This topic focuses on environmental issues such as energy management, carbon emission reduction, air quality, renewable energy use, and pollution. The educational objective is clearly to inform and raise awareness about these critical issues, highlighting the negative consequences, as suggested by the words "negative", "critical" and "consequence". The idea is that online multimedia resources can promote responsible and sustainable practices ("responsible"). The primary recipients are high school or university students.
 - Improving educational practices for the environment. This topic is not specifically focused on a particular environmental objective but rather discusses ways to improve students' cognitive activities. The characteristic words include "class", "advance", "achievement" and "cognitive". Key practices for enhancing student performance include fostering good relationships between pupils and between pupils and teachers, interactive lessons, and the use of multimedia materials. Again, the subjects concerned are primary or lower secondary school students.
 - Mobile devices for sustainable tourism. This topic highlights portable devices as tools for promoting sustainable development and has been labeled "mobile devices for sustainable tourism". According to the reviewed articles, this involves applications that raise environmental awareness through games or digital guides for natural pathways. The recipients of these activities include students and visitors to natural parks and protected areas. The goal is to increase sustainable tourism. The characteristic words are "park", "explore", "observe", "visitor" and "digital".
 - STEM curricula for environmental awareness: This topic defines the field of education in STEM disciplines. The characteristic words are "college", "science", "scientist", "STEM" and "engineer". The idea is to improve curricula, especially academic ones, to promote greater environmental awareness. This topic does not refer to any specific ICT; digital tools are mentioned broadly as elements to be integrated into traditional teaching methods. Mentioned approaches include internet-based teaching, informal practices, partnerships, internationalization, and interdisciplinarity. The recipients are university students and teachers.
 - Technologies for sustainable development. This topic does not highlight specific ICTs but includes a range from immersive technologies to digital photography, multimedia in general, and IT systems for project management. The characteristic words are "green", "future", "sustainability", "ensure" and "ESD". The specific theme of EE here is sustainable development. The goal is to ensure that students develop skills and standards that promote environmental sustainability while also paying attention to cultural elements. The recipients are university students in STEM degree programs, as the focus is on future professionals and experts who need to be trained in this aspect.
 - GIS for natural area management. This topic addresses the use of mapping and visualization technologies, such as satellite images and online mapping systems, to provide accurate and detailed visual representations of landscapes. It is labeled "GIS for natural area management". The educational goal is centered on learning and managing geographical and environmental information to study and manage various landscape aspects. The recipients are clearly from the academic environment, as these sophisticated technologies would rarely find application in other educational contexts. The characteristic words are "map", "situate", "space", "place", "geography" and "landscape".
 - Conservation of biodiversity through platformization: The educational objective of this topic is to promote practices useful for the conservation of ecosystems and biodiversity, labeled "conservation of biodiversity through platformization". Education focuses on the importance of natural resource management and habitat protection. The mentioned technologies mainly include social media and specially created platforms as tools to raise awareness and

support campaigns. The characteristic words are “biodiversity”, “ecosystem”, “river”, “water” and “forest”. In addition to students, the recipients of these practices include residents and the broader community, suggesting an intent to involve a wide range of individuals and groups in understanding and protecting the environment.

Table 1. Taxonomy of ICTs in Environmental Education

| ICT | AIM | MAIN PARTICIPANTS | MAIN USAGE |
|---|---|------------------------------------|---|
| Virtual reality and simulations | Spreading environmental awareness | Primary and middle school students | Visiting virtually inaccessible places |
| Online multimedia resources | Fostering clean energy | High school and college students | Learning environmental practices |
| Mobile devices | Promoting sustainable tourism | Tourists of protected areas | Guiding tourists during their visit |
| Immersive technologies, digital photography | Promoting sustainable development | College students, experts | Spreading sustainable practices |
| GIS | Managing natural areas | College students | Managing natural areas |
| Social media and platforms | Supporting conservation of biodiversity | Students, locals | Promoting biodiversity conservation practices |

4. Discussion

The proposed ICT taxonomy broadly accounts for the many usages of technology in EE while identifying the most common ones, aligning with current literature on how these processes tend to unfold. For example, employing immersive simulations with VR that enables visiting otherwise inaccessible or limited environments and resources, as reported by Kavanagh *et al* (2017). VR is also a peculiar topic because of the ample usage of the term “environment” within the context of simulations, rendering automatic retrieval of documents of its application in EE tricky. Most notable in the collection is the absence of AI as an influential technological driver of EE. This can be explained by the time lag between the resurgence of this topic after significant advancements in Natural Language Processing (NLP) and its limited coverage by academic publishing in this sector as of the date of data gathering. While limited in volume, the collection still reveals several documents employing or discussing AI systems (Arnold & Jantke, 2022; Cao & Jian, 2024). It is nevertheless important to highlight the relevance of recent studies exploring applications of AI systems in EE and within education: while a consensus exists about the opportunities and the challenges posed by the vast array of technologies considered part of AI, there is disagreement on acceptable usage (Holmes *et al.*, 2022), necessary safeguards (Baker & Hawn, 2022) and the very approaches devised to implement them, such as AI fairness (Barocas, Hardt, & Narayanan, 2023; *Sripakash et al.*, 2024). EE is a particular area of application, because of the known environmental threats posed by AI system production pipelines, calling for cautious approaches (Nishant, Kennedy, & Corbett, 2020) and critical evaluations (Cooper, 2023) even when faced with positive potential outcomes (Huang, 2018; Chang *et al.*, 2023), and a focus on AI Literacy (Holmes *et al.*, 2022).

The results suggest that the democratization of technologies (Sattaburuth & Prachyanun, 2022) is indeed progressing, adapting them to a broad range of users and purposes. A deterministic perspective, overestimating the benefits of technologies in pedagogical practices without considering specific contexts or empirical data, should be avoided (Hallström, 2022; Peruzzo *et al.*, 2022). It is essential to consider the affordances of technologies, i.e., their capabilities and

opportunities, to understand why they are adopted for specific purposes. Preferences in the use of technologies strongly depend on the specific objectives for which they are implemented, but an analysis limited to this aspect may overlook the real challenges and limitations that affect the effective implementation of ICTs, for example, within consolidated pedagogical models. These consolidated models can be challenging to modify, thereby limiting technology usage in the educational context (Flavin, 2017).

Sociological reflections are central for contextualizing technological adoptions. As previously discussed, the level of acceptance of technology can play a crucial role in determining the success of technology-based educational interventions (Masrom, 2007). Moreover, the digital divide remains a significant barrier to equitable access to technology-enhanced EE. Disparities in economic resources, digital infrastructure and digital literacy can lead to unequal learning opportunities (Hargittai, 2003). While urban and well-funded institutions often benefit from advanced tools such as VR and AI, rural or underprivileged communities may lack the necessary technological infrastructure, further exacerbating educational inequalities. These disparities may also be reinforced by educators and pedagogical professionals, whose varying levels of training and familiarity with digital tools can influence how technology is implemented in educational contexts (Sulaiman *et al.*, 2013). EE itself can be a problematic topic insofar as acceptance levels vary depending on multiple factors, including socio-demographic variables, national context, and social environment (Moustairas *et al.*, 2022; Sriprakash *et al.*, 2024).

With technological democratization potentially enabling practices reinforcing existing inequalities, such as lock-in effects and contradictory relationships between technology usage and environmental education's goals, caution and continuous scrutiny is deemed necessary. This study contributes to this effort by providing a structured taxonomy that serves as an initial step toward identifying innovative applications of technology in EE, considering technology acceptance, acceptance of EE, and the specific characteristics of technology in relation to its pedagogical purpose.

Conclusions

It is important to present the main limitations of this study, starting with the limitations of bibliometrics. Firstly, there may be issues with reproducibility, such as articles being retracted for reasons such as data manipulation, incongruent results, plagiarism, or copyright infringement. Another significant limitation of bibliometric analyses, particularly evident in this study, is the inability to fully comprehend a topic, given the absence of a perfect query capable of encompassing the entire subject under examination. This limitation is exacerbated in our study for several reasons. Firstly, as discussed in the introduction, the topics and scope of EE have a significant overlap with those of ESD, rendering clear boundaries between the two concepts and formulating adequate queries difficult. Furthermore, the analyses themselves have revealed that EE manifests in multiple modes and approaches, adding layers of complexity, since each approach may have terminological and conceptual specificities that are difficult to capture with a single bibliometric query. This study falls victim to this aspect, reporting a wide diversity in the number and consistently unproductive sources on the topic. Another significant limitation of bibliometric analysis, extendable to environmental studies, concerns the use of the term "environment" in search queries. This term possesses significant semantic ambiguity that can drastically reduce the precision of the obtained results, being used to refer to both the natural environment or biosphere, including ecosystems, biodiversity, etc. and different environments such as work, learning, or even virtual reality environments. This semantic ambiguity results in queries containing "environment" gathering a heterogeneous set of documents addressing vastly different topics. This precision issue translates into greater difficulty in filtering results to isolate studies that genuinely focus on the environment. A further limitation regarding the formulation of the search query concerns the use of the truncation * for the word "technology". As mentioned, while this

approach was aimed to balance recall and precision, it may have led to a slight underestimation of relevant documents by excluding more complex inflected forms of the term. Conversely, using a broader truncation such as “technolog*” would have significantly expanded the dataset, incorporating terms such as technological and technologist, shifting the focus toward professional roles rather than technology itself. This challenge, combined with the semantic ambiguity of the term “environment”, highlights the inherent difficulty of designing a single bibliometric query capable of fully capturing the nuances of EE without introducing excessive noise into the dataset. Future research may refine these methodological choices by employing more sophisticated query strategies to enhance both recall and precision.

A final limitation of the analysis, applicable to all studies utilizing multiple databases concurrently, pertains to the need for heightened attention to cleaning and aligning databases. When integrating data from diverse sources with distinctive characteristics there may be cases of duplications, variations in metadata, and discrepancies in bibliographic references that require careful handling. In any case, the bibliometric analysis followed by textual analysis has proven particularly fruitful. The biblio-textual approach, besides providing an additional descriptive source of the phenomenon, supports the interpretation of results from both perspectives. The sequence of operations remains crucial, influencing interpretation, especially in supervised procedures like LDA.

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