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Astrobiology, Education and UNESCO Global Geoparks: Exploring Epistemic Invisibility in Scientific Databases through a Comparative Bibliometric Study

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This study examines the epistemic visibility of educational research at the intersection of astrobiology, science education and UNESCO Global Geoparks (UGGps) from a critical environmental education perspective. Using a comparative bibliometric analysis of Web of Science and Google Scholar, it reveals marked disparities in the indexing and accessibility of publications on these themes. While Google Scholar retrieved 113 documents linking education, astrobiology and geoparks, Web of Science returned none. Consequently, we broadened the search to include alternative conceptual associations such as "Geopark and Planetary Analogue" and "Geopark and Education". The results indicate that educational practices and discourses in this field remain largely invisible in dominant academic repositories, despite growing interest and innovative applications in informal science learning contexts. These findings highlight the need to broaden visibility criteria in academic research and to question the epistemological assumptions of indexing systems, contributing to wider debates on epistemic environmental justice and knowledge pluralism in science education.

Introduction

Astrobiology, the scientific study of life in the universe, has gained increasing visibility in science education, partly driven by advances in space exploration and digital communication technologies. These developments enable the public to witness scientific discovery in real time, fostering both a sense of participation and fascination with the unknown (Martins et al., 2017; Capova et al., 2018; Malaterre and Lareau, 2025). As new planetary missions and extraterrestrial research flourish, space has become a powerful symbolic and pedagogical arena, offering unique opportunities to connect scientific inquiry with global concerns such as environmental degradation, sustainability and ethical responsibility (Lucas and Spencer, 2020; DeWitt and Bultitude, 2020).

Amid growing calls for more critical and interdisciplinary approaches to science education, astrobiology offers a promising avenue for cultivating STEAM competencies and rethinking the human–planet relationship. As Hodson (2003) argued, science education should help to envision alternative futures rather than reproduce dominant paradigms. This position resonates with Sterling's (2010) advocacy for transformative learning in sustainability education, an approach that challenges existing assumptions, engages with uncertainty and embraces systemic change. Yet, while astrobiology's scientific prestige grows, its educational implications remain underexplored in scholarly literature and formal curricula. This disconnect raises questions about which forms of educational knowledge are considered visible, valuable and indexable in the current academic system.

In parallel, UNESCO Global Geoparks (UGGps) have been promoted as innovative educational spaces that blend geoscience, heritage and community engagement. These territories function as living laboratories, offering rich opportunities for place-based and outdoor education rooted in cultural and ecological diversity (Catana and Brilha, 2020; UNESCO, 2025; Rodrigues et al., 2025). As of 2025, 229 UGGps have been designated across 50 countries, reflecting their growing institutional legitimacy. Some geoparks have begun integrating astrobiology and planetary sciences into their educational offerings-such as astronaut training in volcanic landscapes (Massironi et al., 2023) or simulations of lunar environments in lava tubes (Barcelos and Pires, 2024), thereby blurring the boundaries between scientific exploration and environmental education.

Despite these advances, a structural problem persists: the educa-

tional role of UGGps, particularly their engagement with planetary sciences, remains largely invisible in major academic repositories. Recent analyses suggest that while geoparks are prolific in petrological, geographical or biodiversity research, the educational practices developed within them are often confined to grey literature, conference proceedings or non-indexed journals (Martínez-Martín et al., 2023). This phenomenon reflects broader dynamics of academic exclusion that affect interdisciplinary, informal and place-based educational knowledge, highlighting, as Stevenson (2007) noted, the contradictions between the transformative goals of environmental education and the instrumental logic of institutional schooling and publication. More broadly, the tensions described are not exclusive to UNESCO Global Geoparks or to astrobiology. Similar dynamics of visibility and exclusion affect many emerging or interdisciplinary fields, particularly when their outputs are disseminated through non-traditional channels, grey literature or locally oriented publications. Recent debates on research assessment have drawn attention to the limitations of evaluation systems that rely heavily on a narrow set of high-impact databases and citation metrics, and international initiatives such as the Coalition for Advancing Research Assessment (CoARA) are actively calling for more diverse and context-sensitive criteria. In this study, we do not claim that UGGps and astrobiology constitute a unique case, but rather use this intersection as a focused empirical lens through which to examine more general questions of epistemic environmental justice in science education (Coalition for Advancing Research Assessment, s. f.).

In this context, the present study examines the representation of the concepts “Astrobiology,” “Education,” and “Geoparks” in two major academic databases: Web of Science and Google Scholar. By conducting a bibliometric and comparative analysis, we aim to reveal trends, gaps, and asymmetries in the indexing and visibility of educational research within these thematic intersections. In doing so, we seek to contribute to current debates on epistemic justice, environmental literacy, and the evolving nature of science communication in the Anthropocene. The future of environmental education depends not only on pedagogical innovation but also on confronting the epistemological hierarchies that determine which forms of knowledge become visible, recognised, and institutionally valued in global academic circuits (Wals, 2010).

Methods and Materials

This study employs an exploratory bibliometric approach to investigate the academic visibility of the intersection between astrobiology, education and UNESCO Global Geoparks (UGGps). Rather than following a formal systematic review protocol (e.g., PRISMA), the aim is to highlight patterns of inclusion and omission in widely used academic databases, as an entry point to broader discussions on the legitimisation of educational knowledge.

To that end, Boolean keyword combinations were used to conduct searches in two contrasting databases: Web of Science (WoS), known for its stringent indexing and disciplinary filtering, and Google Scholar (GS), characterized by broader coverage, including grey literature, educational reports, and non-indexed journals. This contrast enabled us to examine how different forms of scientific communication influence the presence or absence of pedagogical research on astrobiology and geoparks. Three core objectives guided the search strategy:

1. To obtain a broad overview of how astrobiology and education are connected in academic literature.

2. To investigate the extent to which UNESCO Global Geoparks appear as educational environments in relation to astrobiology.

3. To identify discrepancies in publication patterns and visibility across both databases and reflect on their implications for science education and epistemic justice.

Searches were performed using combinations of the keywords "Education," "Astrobiology," and "Geopark" (and their variants) in April 2025. The resulting datasets were systematised in tables and visualised through bar graphs and citation maps. Additionally, VOSviewer was used to generate conceptual maps of author co-citation and keyword clustering within Google Scholar. Comparable metrics from Web of Science were extracted manually, given the more restricted and curated nature of its indexing system.

This methodology does not aim for exhaustive coverage, but rather illustrates the dynamics of visibility and omission that shape how certain educational practices, particularly those situated at the intersection of planetary sciences and informal learning, are represented within academic knowledge systems.

Results and Discussion

The results retrieved from both academic databases are presented in tables and figures (Table 1; Figs. 1 and 2). Notably, Web of Science yielded no records directly linking the terms "Education", "Astrobiology," and "Geoparks." This finding reveals not only the scarcity of indexed research in this specific intersection but also the possible exclusion of educational contributions from formal recognition within dominant academic repositories. To address this absence, we broadened the search parameters to include adjacent conceptual pairings: Geopark and Astrobiology, Geopark and Planetary Analogue, and Geopark and Education. These combinations enabled a more nuanced exploration of the presence and categorization of relevant literature across disciplines.

The data were analysed in terms of publication volume, distribution over time, thematic classification, and author prominence (see Table 2;

Table 1. Relative frequency of results obtained from Google Scholar searches

Search Terms	Number of Results	Percentage
Education	8,550,000	100%
Education AND Astrobiology	23,400	0.27%
Education AND Astrobiology AND Geopark	113	0.0013%

Note. Data obtained in April 2025 using Boolean keyword combinations in English on Google Scholar.

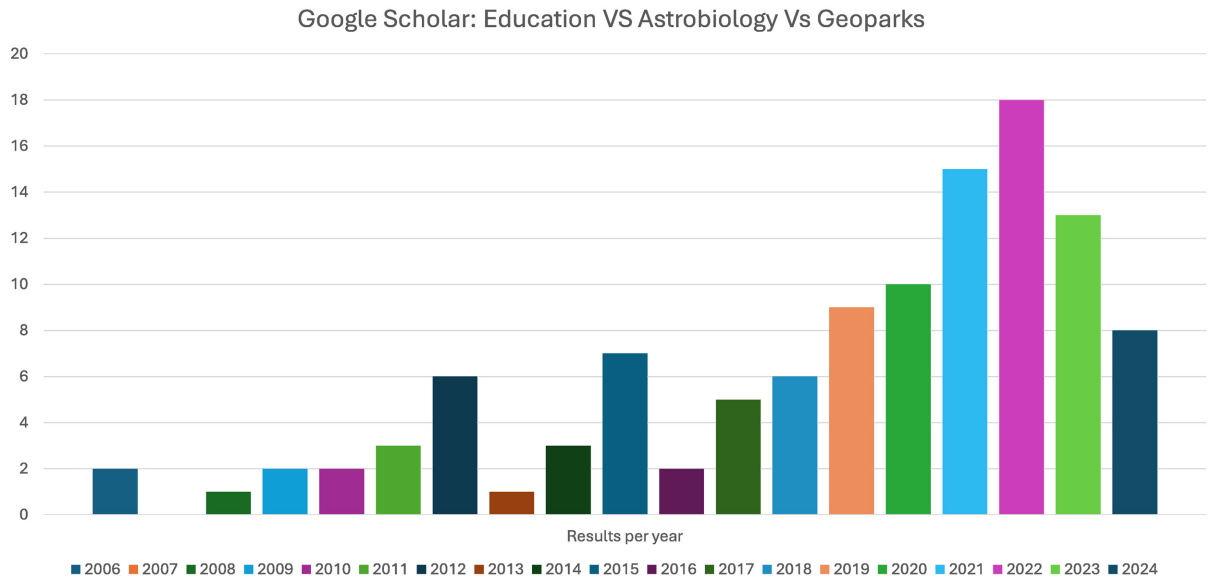

Figure 1. Publication trends for Education, Astrobiology, and Geoparks in Google Scholar.

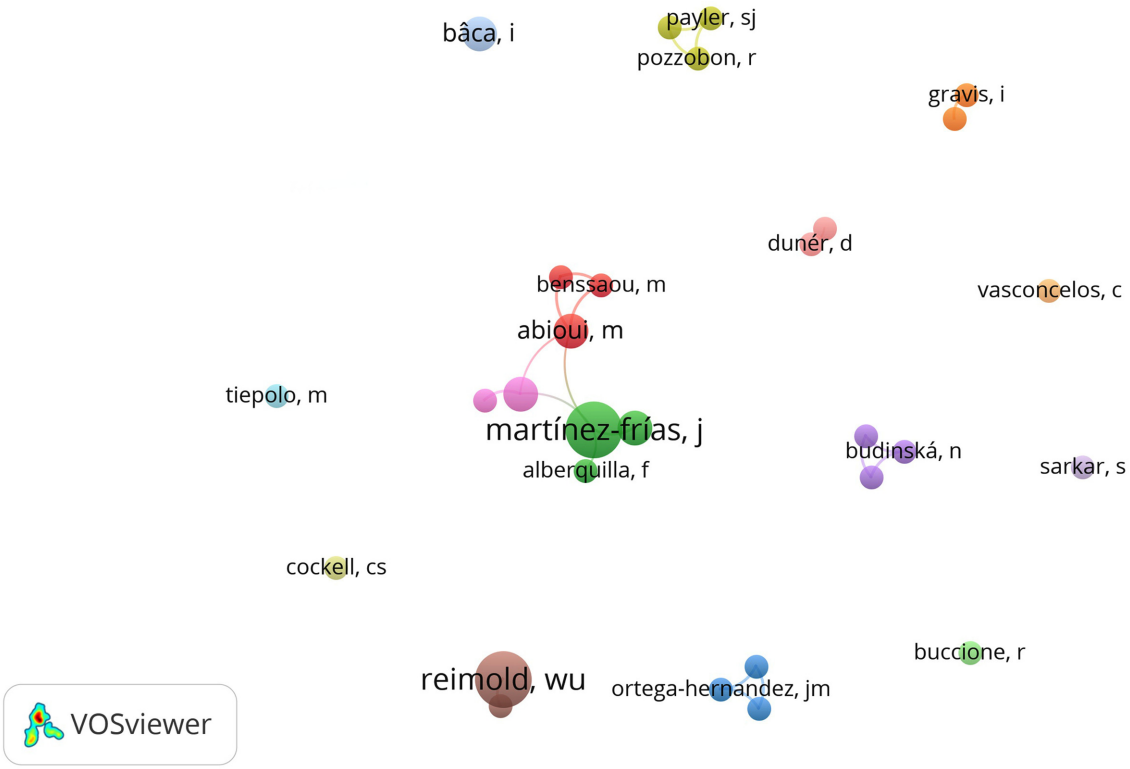

Figure 2. Citation map of the most cited authors in Education, Astrobiology, and Geoparks (Google Scholar).

Figs. 5 and 6). This extended analysis provides a clearer understanding of how astrobiology-related educational work, particularly when embedded in informal, place-based settings, such as UNESCO Global Geoparks, remains fragmented and inconsistently represented across the scientific literature.

The data retrieved from Google Scholar reveal a clear upward trend in publications at the intersection of astrobiology and education, particularly between 2017 and 2022. This pattern suggests an increasing academic interest, although it remains modest in volume. In relative terms, only 0.27% of all education-related publications explicitly mention astrobiology, and a mere 0.0013% include references to both astrobiology and geoparks. Furthermore, the citation map (Fig. 2) shows a highly dispersed author landscape, indicating a lack of consolidated scholarly networks in this emerging intersection.

The findings from Web of Science are even more striking. No indexed results were found that simultaneously link Education, Astrobiology, and Geoparks. Even when broadening the search parameters to include related terms such as "Planetary Analogue" and "Geopark,"

Table 2. Search results and relative frequencies in Web of Science

Search results including "Education" terms:

Search Terms	Number of Results	Percentage
Education	3,707,781	100%
Education AND Astrobiology	211	0.0056%
Education AND Astrobiology AND Geopark	0	0

Search results including "Geopark" terms:

Search Terms	Number of Results	Percentage
Geopark	1,504	100%
Geopark AND Astrobiology	1	0.066%
Geopark AND Planetary Analogue	4	0.26%
Geopark AND Education	264	17.55%

Note. Boolean keyword searches were conducted in April 2025 on Web of Science Core Collection. No language or time filters applied.

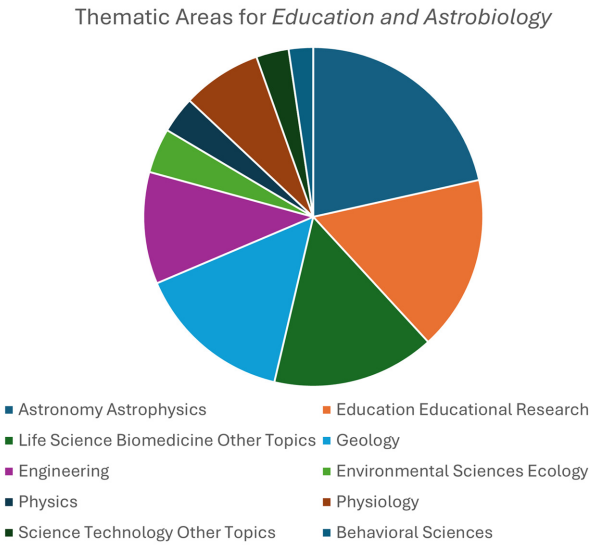

Figure 3. Thematic distribution of publications regarding Education and Astrobiology in Web of Science.

the total number of publications remains minimal. For instance, only 0.0056% of all education-related entries mention astrobiology, and just 17.55% of studies focused on geoparks address education directly. These figures are particularly troubling considering that UNESCO Global Geoparks are explicitly conceived as educational territories. The thematic classification within Web of Science further reveals that several articles relevant to education are not categorised under educational research, reinforcing their invisibility within formal academic circuits.

This misalignment between the content and indexing structures of major databases reveals systemic epistemological hierarchies that shape what is perceived, valued, and validated as scientific knowledge. As Stevenson (2007) noted, transformative forms of environmental education often conflict with the instrumental rationality embedded in institutionalised systems of schooling and publication. Although systematic reviews in environmental education strengthen the evidence base for place-based and informal practices, such as those implemented in Geoparks, many of these critical methodologies remain underrepresented in mainstream databases. This is evident even for climate change

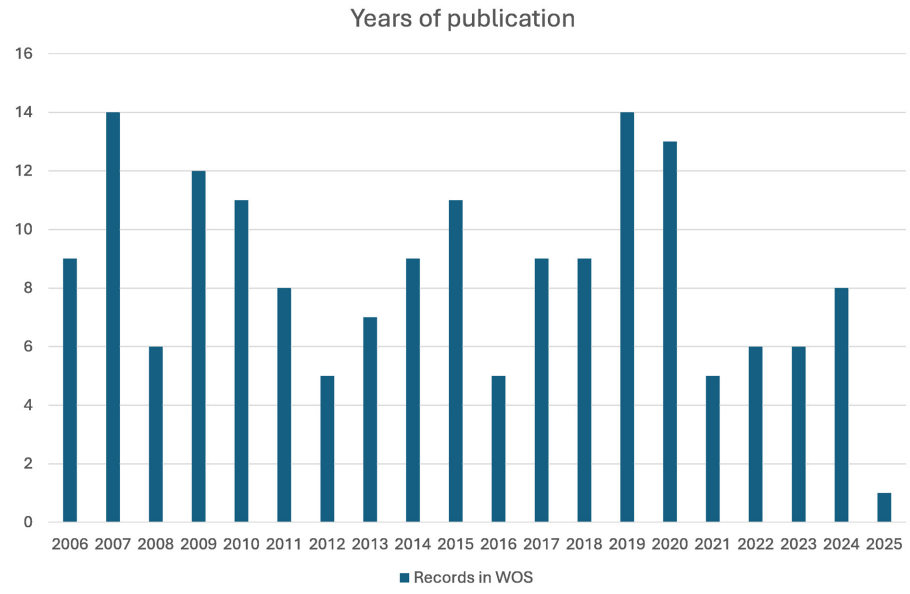

Figure 4. Publication years distribution regarding Education and Astrobiology in Web of Science.

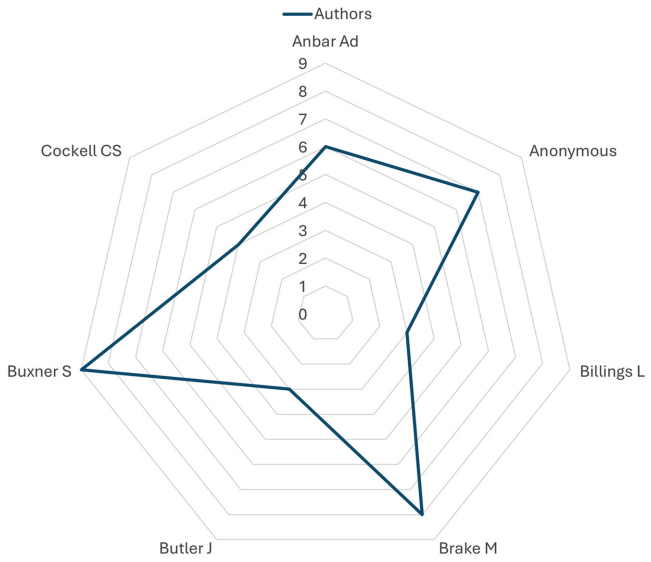

Figure 5. Leading authors in publications regarding Education and Astrobiology in Web of Science.

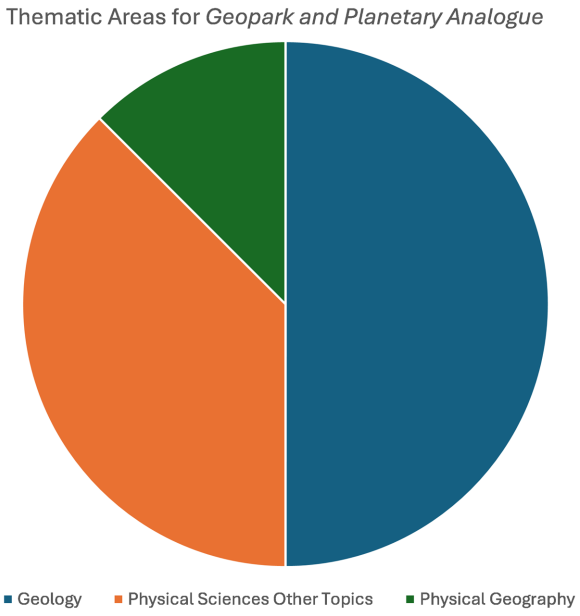

Figure 6. Thematic areas of Geopark and Planetary Analogue publications (Web of Science).

literacy, as Sato and Park (2024) show how literacy assessment frameworks are emerging in the educational literature yet require broader recognition and integration across databases. Our findings support this view: educational research developed in informal, place-based settings, especially when interdisciplinary or speculative, as is the case with astrobiology, tends to be excluded from dominant frameworks of scientific recognition.

From an educational perspective, the intersection of astrobiology and UGGps can be made more tangible through specific types of activities. For example, volcanic fields, lava tubes, and impact structures within some UGGps are already being used as planetary analogue sites to discuss how scientists search for traces of life on Mars or other celestial bodies. School programmes can invite students to compare local geosites with terrains explored by current space missions, fostering critical reflection on habitability, planetary processes and the limits of Earth-based analogies. Citizen-science initiatives and night-sky interpretation events can combine astronomy, geology and environmental ethics, linking fascination with the cosmos to questions of sustainability and stewardship of the Earth. While not all these activities are currently implemented in every UGGp, they illustrate the kind of place-based, interdisciplinary learning opportunities that this setting can support.

The disparity between the two databases underscores this problem. Google Scholar retrieved 23,400 documents on education and astrobiology, while Web of Science indexed only 211. Such a gap suggests that much of the literature in this field exists in non-indexed formats, including grey literature, online repositories and non-peer-reviewed publications (Jacsó, 2005; Martín-Martín et al., 2018; Singh et al., 2021). While Google Scholar's broader scope includes materials of variable quality, it also provides access to alternative forms of knowledge production that are often excluded from mainstream citation ecosystems (Delgado López-Cózar and Repiso, 2013; Halevi et al., 2017). For a comprehensive understanding of emerging educational fields, both types of platforms therefore offer complementary insights.

These patterns resonate with ongoing international debates on how research is assessed and valued. If evaluation systems privilege publications indexed in a small number of selective databases, educational work that is locally grounded, produced in collaboration with communities or disseminated through non-traditional outlets will remain structurally disadvantaged. Emerging initiatives in research assessment, including those promoted by the Coalition for Advancing Research Assessment (CoARA), explicitly call for recognising a wider diversity of research outputs, practices and impacts. Our findings suggest that the educational activities developed in and around UGGps could benefit from such a shift, as many of them currently lie at the margins of conventional citation and indexing systems (Coalition for Advancing Research Assessment, n.d.).

These findings gain particular urgency in the current educational landscape, marked by increasing digitization, rapid content consumption, and declining attention spans (Yousef, 2025). Social media platforms such as TikTok and Instagram are reshaping cognitive habits and student expectations, creating new challenges and opportunities for science education (Zachos et al., 2018; Lecona et al., 2025). Within this context, astrobiology can function as a pedagogical counterweight: a scientifically rigorous, interdisciplinary field that taps into students' imagination and existential curiosity. As argued by Sterling (2010), education for sustainability must engage learners both affectively and ethically, rather than merely informing them. Astrobiology offers precisely this: a way to reconnect science with wonder, responsibility, and a long-term vision of planetary stewardship.

In sum, the exclusion of educational studies on astrobiology and geoparks from indexed scientific databases reflects not only a bibliometric gap but a deeper epistemic asymmetry in how knowledge is classified, disseminated, and legitimised. Bridging this gap requires not only promoting innovative pedagogies but also challenging the structures that determine whose knowledge counts in the first place.

Conclusions

Astrobiology and planetary sciences are rapidly consolidating their relevance in contemporary science education. These disciplines not only spark fascination with the origin and evolution of life in the universe but also provide a meaningful entry point for addressing broader issues, such as sustainability, ethical responsibility, and the future of humanity. Their inherent interdisciplinarity makes them ideal platforms for cultivating STEAM competencies, skills that are increasingly necessary to navigate the social and technological transformations of the 21st century.

UGGps, meanwhile, have become exemplary spaces for experiential, place-based, and socially relevant science education. Beyond their role as conservation territories, UGGps integrate geodiversity, cultural heritage and community engagement within a single governance framework, which explicitly includes education as a core mandate. In several cases, their geological features have been recognised as planetary analogue environments and used in astronaut training or analogue missions (Martínez-Frías and Mateo, 2019; Massironi et al., 2023; Barcelos and Pires, 2024). This unique combination of rich geological settings, institutional recognition and educational responsibilities makes certain UGGps particularly promising venues for integrating astrobiology and planetary sciences into science education.

However, this study also reveals a persistent structural asymmetry in the visibility of such educational practices within academic publishing. Despite a discernible growth in publications addressing these intersections, particularly in open and alternative repositories, the presence of indexed literature in mainstream databases remains minimal. This discrepancy is not merely technical but epistemological: it reflects longstanding hierarchies in what types of research, knowledge formats, and dissemination channels are deemed legitimate, citable, and valuable within academic systems.

Focusing exclusively on selective, high-impact bibliographic databases can obscure innovative and context-rich contributions that flourish in informal, interdisciplinary, or digitally mediated environments. Educational practices in geoparks, for instance, are often documented in grey literature, conference proceedings, and project reports that rarely meet the indexing criteria of dominant platforms. As a result, crucial educational work remains invisible in global academic circuits, limiting its potential influence on policy, teacher training, and curricular innovation.

To foster a more inclusive and critically reflexive science education, it is essential that the research community not only broaden its search strategies but also re-examine the standards by which educational knowledge is validated and disseminated. Recognising the educational value of astrobiology and planetary sciences within UGGps requires overcoming the dichotomy between formal and informal education and acknowledging that not every UGGp will be an equally suitable setting for these themes. The relevance of astrobiology depends on the specific geological features, interpretive frameworks and community priorities of each territory, and should therefore be approached in a context-sensitive rather than uniform manner. By "instrumental logics", following Stevenson (2007), Sterling (2010) and Wals (2010), we refer to educational and publishing regimes that prioritise short-term, quantifiable outputs, such as standardised test scores, narrow performance indicators or citation metrics, over deeper, transformative learning aims. Challenging these logics is a precondition for legitimising innovative, place-based pedagogies that connect planetary exploration, environmental justice and local forms of knowledge.

Ultimately, this study advocates for increased visibility, institutional support, and academic recognition of educational initiatives that aim to foster environmental literacy, planetary awareness, and scientific citizenship. Promoting these intersections can contribute to reconfiguring science education as a transformative endeavour, one that prepares learners not only to understand the world but to imagine and construct more just, sustainable, and cosmically conscious futures.

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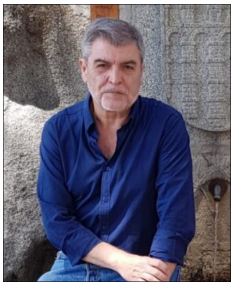

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