



BIBLIOMETRIC ANALYSIS OF SUSTAINABLE EDUCATION AND STUDENT BEHAVIORAL CHANGE MODELS

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ABSTRACT

This study aims to map the structure and development of literature in the fields of Eco-Realistic Mathematics Education, Contextual Numeracy Environmental Behavior, and Theory Planned Behavior Education in the context of sustainable education and student behavior change. The method used is a quantitative descriptive bibliometric approach with data sources from the Dimensi database. Data analysis was conducted using VOSviewer software to map collaboration networks, thematic clusters, term density, and publication trends based on countries, institutions, authors, and keywords. The results show that the literature is still dominated by the theme of Theory Planned Behavior Education, while Eco-RME and Contextual Numeracy Environmental Behavior are still in the early stages of development with a limited number of publications. The network structure shows a concentration on certain countries such as China, Malaysia, and Turkey, as well as institutions that are centers of research collaboration. Keyword analysis shows that terms such as behavioral intention, teachers, learning, technology, and sustainability are the main focus in the literature. The conclusion of the study shows that this field is still fragmented and requires stronger conceptual integration to connect contextual mathematics education, environmental numeracy literacy, and behavioral theory.

Keywords: bibliometric analysis, Eco-RME, Theory of Planned Behavior, contextual numeracy, environmental behavior

INTRODUCTION

Sustainable education has become a key agenda in the global education system due to the escalating environmental crisis and the need to foster environmentally friendly behaviors from an early age. The Sustainable Education Framework positions education as a holistic process that integrates knowledge, values, attitudes, and actions into primary and secondary school curricula. UNESCO emphasizes that Education for Sustainable Development (ESD) focuses not only on knowledge transfer but also encompasses competencies, attitudes, and a learning environment that supports the development of sustainable behaviors holistically (Hemmer et al., 2024). This framework demonstrates that environmental learning cannot be separated from the pedagogical context and school culture, as all three influence each other in shaping students' sustainability literacy. This integration is reinforced by cross-country curriculum studies that show that ESD objectives have been

operationalized in various subjects, including geography, although the results still show variation in the implementation of environmental values and attitudes (Bagoly-Simó, 2024; Miao et al., 2022). This situation confirms that the implementation of environmental education remains uneven in connecting knowledge with students' concrete actions.

The main problem in current environmental education lies in the gap between environmental knowledge and students' actual behavior. Many curricula incorporate sustainability concepts, but these have not consistently resulted in changes in attitudes and actions aligned with ESD goals. Studies show that attitudinal and value dimensions often receive insufficient explicit attention in learning design, resulting in inadequate sustainability literacy (Miao et al., 2022). Furthermore, ESD implementation is also influenced by structural factors such as school policies, teacher competency, and school climate, which are not always aligned with sustainability education principles (Hemmer et al., 2024; Tinilau et al., 2024). This suggests that environmental education depends not only on curriculum content but also on broader support systems, including school leadership and teacher professionalization (Benischek et al., 2023). Thus, there is an urgent need to examine how sustainability education frameworks are actually implemented in learning contexts that can meaningfully change student behavior.

Beyond curriculum aspects, behavior change theory provides an important foundation for explaining how students adopt environmentally conscious behaviors. The Theory of Planned Behavior (TPB) explains that individual behavior is influenced by attitudes, subjective norms, and perceived behavioral control, which shape intentions before action occurs. In educational contexts, the TPB has been widely used to explain how learning interventions can influence students' pro-environmental intentions and behaviors through changes in attitudes and social perceptions (Adeyemi et al., 2025; Rahmawati et al., 2024). Research shows that all three TPB constructs contribute significantly to shaping environmental behavior, although the strength of their influence can vary depending on the learning context and student characteristics (Fathonah & Nastiti, 2024). The use of the TPB in education also shows that structured learning can raise awareness, strengthen social norms, and enhance students' perceived behavioral control over environmental actions (Hamdan et al., 2023). This suggests that behavioral change does not occur spontaneously, but rather through psychological processes that can be designed into learning.

However, the integration of sustainability education and behavior change theory has not been comprehensively studied within a single analytical framework. Previous studies have tended to separate ESD curriculum studies from TPB-based behavioral psychology studies, thus not providing a complete picture of how knowledge, values, attitudes, and behavioral control can be constructed simultaneously in contextual mathematics learning. On the other hand, bibliometric studies indicate that research on environmental education and pro-environmental behavior is growing rapidly but remains fragmented across different research clusters such as curriculum, pedagogy, and social behavior (Pedraja-Rejas et al., 2023; Rueda et al., 2023). This fragmentation suggests the need to integrate these various approaches to produce a more comprehensive educational model. Furthermore, research mapping analysis indicates that the relationship between environmental education and behavioral change is still evolving and has yet to reach a stable conceptual consensus (Lasino et al., 2023). Therefore, bibliometric-based research is crucial for mapping the development direction, gaps, and opportunities for integration of these concepts.



METHOD

This study uses a bibliometric approach with a quantitative descriptive design to map the development of literature in the field of sustainable education and student behavior change. Research data was obtained from the Dimensions database because it has a broad and structured coverage of scientific articles in the fields of education, environment, and behavior. The literature search process used three main keywords, namely "Eco-Realistic Mathematics Education", "Contextual Numeracy Environmental Behavior", and "Theory Planned Behavior Education" to capture the relationship between contextual mathematics education, environmental numeracy literacy, and behavior change theory. The research sample was in the form of scientific publication metadata that included title, author, year of publication, institutional affiliation, country, keywords, and citations from articles relevant to a certain time period according to the Dimensions search results. The research instrument used was bibliometric data management software such as export files from Dimensions in RIS or CSV format which were then analyzed using VOSviewer for scientific mapping. The data collection procedure was carried out by identifying articles based on keywords, filtering based on topic relevance, downloading metadata, and cleaning data to eliminate duplication and inconsistencies in terms. Once the data was ready, analysis was conducted using VOSviewer to generate network visualization, density visualization, and overlay visualization to observe the development of research trends over time. Additionally, co-authorship analysis was conducted to examine collaborations between authors, organizations, and countries, and co-occurrence analysis to identify relationships between keywords in the reviewed literature. Temporal analysis was used to observe the development of publications between years to identify research growth trends in the fields of Eco-RME, contextual numeracy, and TPB in education. The results of this analysis were then interpreted descriptively to identify research cluster patterns, relationships between conceptual variables, and research gaps that support the development of the Eco-RME model based on the Theory of Planned Behavior.

RESULTS AND DISCUSSION

1. Annual Publication Trends

Publication trend analysis was conducted based on three main keywords: Theory of Planned Behavior Education, Contextual Numeracy, Environmental Behavior, and Eco-Realistic Mathematics Education, obtained from the Dimensions database. In general, the results show that the development of the literature is still dominated by one main domain, namely Theory of Planned Behavior Education, while the other two domains are still in the early stages of development.

For the keyword Theory of Planned Behavior Education, publications began to appear significantly in 2022 with 29 articles. This trend then fluctuated in the following years, with 18 publications in 2023, increasing to 23 publications in 2024, and peaking with 33 publications in 2025. 2026 saw a slight decrease to 31 publications. This pattern indicates that the SDGs in education have become a primary focus of research and have a stable, sustainable trend.

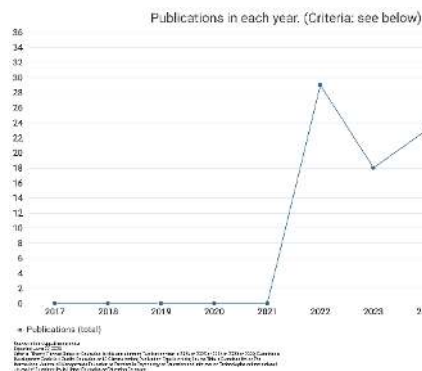


Figure 1 Keyword Theory of Planned Behavior Education

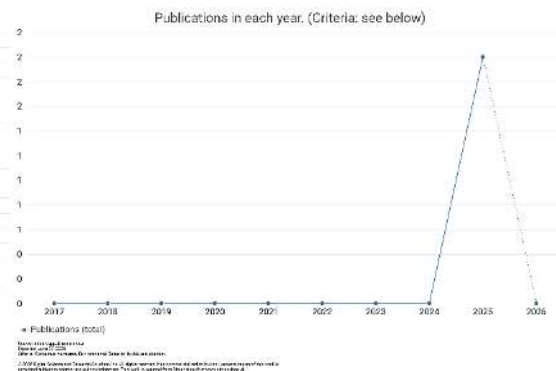


Figure 2 Keyword Contextual Numeracy Environmental Behavior

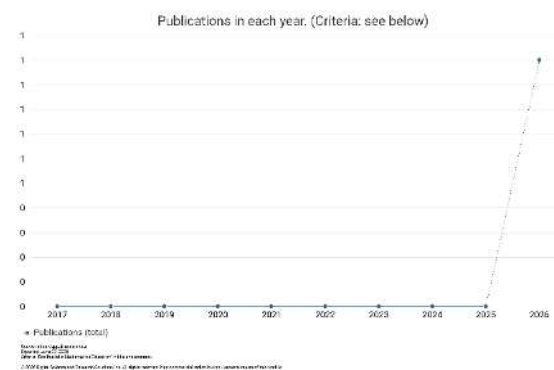


Figure 3 Keyword Eco-Realistic Mathematics Education

In contrast, the keyword "Contextual Numeracy Environmental Behavior" shows very limited development. There were no publications between 2017 and 2024. Two new publications appeared in 2025, and then none were found again in 2026. This indicates that this field is still in its embryonic stage in the scientific literature.

Meanwhile, Eco-Realistic Mathematics Education also shows a very limited pattern. There were no publications between 2017 and 2024, and only one publication appeared in 2025, with no further developments in 2026. This condition indicates that the Eco-RME concept is still very new and has not yet developed consistently in the academic literature.

When the three keywords are combined, it appears that the largest contribution comes from TPB Education, while the other two keywords remain sporadic. The year 2025 marked the peak with a combined total of 36 publications, consisting of 33 TPB Education, 2 Contextual Numeracy Environmental Behavior, and 1 Eco-RME. Overall, this trend indicates that the literature structure is still not balanced across the three domains.

2. Country Network Visualization

The country network visualization shows that research collaborations are distributed across several key countries in the fields of education, technology, and behavior. China emerges as the largest node, indicating a dominant level of publication contribution compared to other countries in the network. Other countries with strong connections in the network include Malaysia, Turkey, Taiwan, Saudi Arabia, the United Arab Emirates, India, and Australia. The red cluster is dominated by Turkey, Spain, the United States, Pakistan, and

Italy, which are interconnected within a single collaborative network. The green cluster shows the connections between Malaysia, Oman, India, and Norway within a single research group. The blue cluster includes Saudi Arabia, the United Arab Emirates, Egypt, Australia, and Romania, which are all connected within the same network. The yellow and purple clusters show the positions of China, Indonesia, Thailand, Taiwan, and Vietnam, which are within a regional connectivity pattern. Overall, the network demonstrates cross-country connectivity through the lines connecting the various clusters.

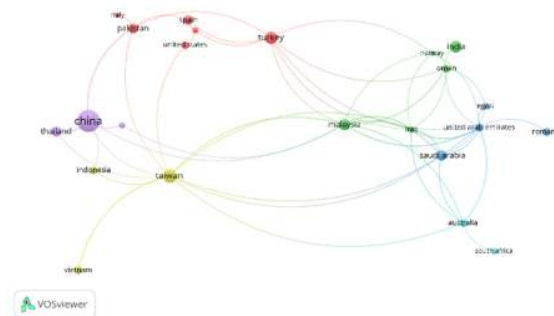


Figure 4 Country Network Visualization

3. Institutional Network Visualization

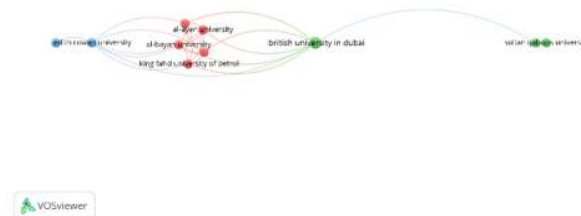


Figure 5 Institutional Network Visualization

The organizational visualization shows the existence of collaboration patterns among higher education institutions in scientific publications. The British University in Dubai appears as a major node connected to several other institutions in the research network. The red cluster consists of Al-Ayen University, Al-Bayan University, and King Fahd University of Petroleum, which are interconnected within a single group. The green cluster shows the interconnectedness of several institutions in different regional areas with relatively strong internal collaboration patterns. Sultan Qaboos University is relatively isolated but still has connections to the main network. Edith Cowan University is in another cluster indicating collaborative relationships with specific institutions. The overall network structure indicates the existence of several groups of institutions formed based on research collaboration

learning, technology, and sustainability, located at the center of the network. Green and yellow zones indicate medium density, including terms such as school, application, educator, and implementation. Blue areas show lower density, including terms such as entrepreneurship, innovation, and COVID. The density distribution shows differences in the intensity of occurrence among terms within the network. The center of the map shows the densest and most interconnected concentration of terms. This distribution shows that some themes are more dominant than others. Overall, the density pattern indicates varying levels of research focus within the literature.

6. Overlay Visualization

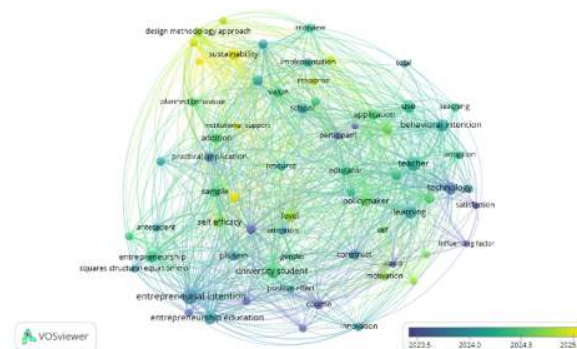


Figure 8 Overlay Visualization

The overlay visualization shows the development of terms based on the time period of research publication. Blue indicates earlier terms, around 2023 to 2024. Green indicates a transitional period in research development. Yellow indicates newer terms, around 2025. Terms such as behavioral intention, teacher, learning, and technology emerged as newer topics in the network. Terms such as entrepreneurial intention and entrepreneurship education emerged earlier. There has been a shift in research focus from entrepreneurship to behavior, learning, and educational technology. The color changes in the network demonstrate the dynamics of literature development over time.

7. Network Visualization

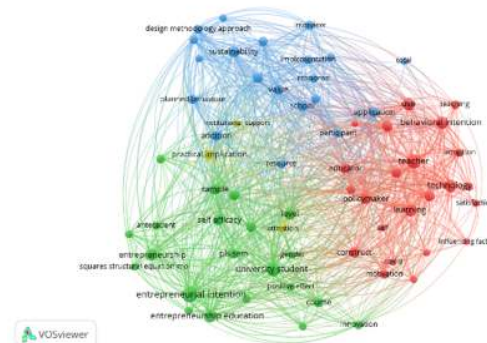


Figure 9 Overlay Visualization

The keyword network visualization shows the interconnectedness of terms in the research literature. Three main clusters are interconnected in a complex network. The red cluster focuses on terms such as behavioral intention, teacher, technology, and learning. The green cluster focuses on entrepreneurship, entrepreneurial intention, and university student. The blue cluster focuses on sustainability, implementation, school, and value. The relationships between clusters are shown through connecting lines that form a dense network structure. The size of the nodes indicates the frequency of occurrence of the terms in the literature. Overall, the network demonstrates extensive connections between research themes.

The bibliometric mapping shows that the literature on Eco-RME, contextual numeracy, environmental behavior, the Theory of Planned Behavior (TPB), and sustainability education forms an uneven global knowledge structure. China dominates the country-level publication network, while the British University in Dubai functions as a major institutional collaboration hub. At the author level, researchers such as Al-Emran, Al-Sharafi, Al-Qaysi, and Ali Norashikin form a dense and influential collaboration cluster. These patterns indicate that scientific production remains concentrated in countries, institutions, and author groups with strong research capacity and international networks. This finding supports previous studies that highlight the role of research ecosystems, institutional support, and cross-institutional collaboration in advancing sustainability education (Pedraja-Rejas et al., 2023; Rueda et al., 2023; Hemmer et al., 2024; Tinilau et al., 2024). Thematic mapping further identifies behavioral intention, teacher, learning, technology, and sustainability as central concepts, confirming the relevance of TPB in explaining how attitudes, subjective norms, and perceived behavioral control influence educational behavior (Hamdan et al., 2023; Rahmawati et al., 2024).

The density and cluster analyses reveal that the literature primarily focuses on the relationship between learning processes, technology use, and behavioral formation. High-density terms, including teacher, behavioral intention, learning, technology, and sustainability, indicate a growing emphasis on integrating knowledge, values, and action in education. Meanwhile, school, educator, implementation, and application occupy medium-density areas, suggesting that teacher competence and institutional readiness remain important implementation factors (Benischek et al., 2023). Three major clusters emerge: learning and technology, entrepreneurship and behavioral intention, and sustainability and school implementation. However, these clusters remain conceptually fragmented. The temporal analysis also shows a shift from entrepreneurship education and entrepreneurial intention toward behavioral intention, teacher learning, sustainability, and technology. The sharp increase in publications after 2022, reaching its highest level in 2025, indicates rapid scholarly growth, although annual fluctuations suggest that the field is still developing and has not yet reached theoretical stability (Miao et al., 2022; Gabriel et al., 2023).

These findings establish the need for an integrative framework that connects Eco-RME, contextual numeracy, environmental behavior, and TPB. The study contributes theoretically by mapping these previously separate domains within a unified scientific structure and methodologically by demonstrating the use of VOSviewer to examine multidimensional relationships among countries, institutions, authors, and concepts. Practically, the findings support the development of a TPB-based Eco-RME model for strengthening elementary students' numeracy skills and environmental behavior through



contextual learning. Teachers should therefore act as facilitators of knowledge acquisition and behavioral development, supported by relevant digital technologies. Educational institutions and policymakers should also promote cross-institutional collaboration and curricula that integrate numeracy, environmental issues, and behavioral competencies. Nevertheless, the findings should be interpreted cautiously because the data were limited to the Dimensions database, the keyword strategy may not capture the entire literature, and bibliometric visualization provides descriptive and exploratory relationships rather than causal evidence.

CONCLUSION

This study concludes that the literature structure in the fields of Eco-RME, Contextual Numeracy Environmental Behavior, and Theory Planned Behavior Education shows a fragmented yet interconnected development pattern within several key clusters. The analysis reveals that the primary domain dominance lies in Theory Planned Behavior Education, which has the most stable and growing publication trend compared to the other two keywords. Meanwhile, Eco-RME and Contextual Numeracy Environmental Behavior are still in their early stages of development with a very limited number of publications. At the structural level, countries such as China, Malaysia, and Turkey are the main centers of scientific production, while the British University in Dubai plays a central role in the collaborative network. At the author level, a core group of researchers dominates knowledge production, particularly in the fields of SDGs and behavioral education. At the thematic level, terms such as behavioral intention, teacher, learning, technology, and sustainability are central to the literature structure, indicating a primary research focus on the relationship between learning and behavior.

These findings provide an important contribution to the development of educational science, particularly in the integration of contextual mathematics education, environmental education, and behavioral theory. This research shows that although these three domains have developed in parallel, there has not been a strong conceptual integration within a single integrated learning model. Therefore, the results of this study provide a scientific basis for the development of an Eco-RME model based on the Theory of Planned Behavior that links contextual numeracy with the formation of students' environmentally conscious behavior. Another contribution of this research is the mapping of the global knowledge structure that indicates the direction of research development and remaining research gaps. This strengthens the research's position as a basis for the development of more comprehensive theories and learning models in the context of sustainable education.

Suggestions for future research include expanding data sources by using other scientific databases, such as Scopus and Web of Science, to enrich the bibliometric analysis results. Further research should also integrate advanced quantitative methods, such as structural equation modeling, to empirically test the relationships between variables. Furthermore, field experiments are needed to test the effectiveness of the TPB-based Eco-RME model in the context of real-life elementary school learning. Longitudinal studies are also needed to examine the long-term impact on students' contextual numeracy and environmental behavior. Future research is also recommended to expand the variables by

incorporating social, cultural, and educational policy factors to make the developed model more comprehensive and contextual.

BIBLIOGRAPHY

- Adeyemi, E., A., Ahn, J.-H., Xu, Z., Muko, H., Baker, &, & M. (2025). Promoting SDGs through education: A Theory of Planned Behavior analysis of Japanese and Nigerian students' sustainability actions. *Sustainable Development*. <https://doi.org/10.1002/sd.3493>
- Bagoly-Simó, P. (2024). Von Stadt, Land, Fluss Zur Nachhaltigkeitskunde: (Irr-)Wege Der Ausgestaltung Des Fachwissens in Den Berliner Geographielehrplänen Der Letzten Drei Jahrzehnte. *Geographica Helvetica*, 79(1), 73–84. <https://doi.org/10.5194/gh-79-73-2024>
- Benischek, I., Beer, R., Beer, G., & Bauer, A. (2023). Lehrer*innen-Kompetenzen Als Voraussetzung Zum Konstruktiven Umgang Mit Diversität In Einem Kompetenzorientierten Unterricht. *R&e-Source*, 10(3). <https://doi.org/10.53349/resource.2023.i3.a1001>
- Fathonah, N., & Nastiti, A. (2024). How Does Gender Affect Pro-Environmental Behaviors? The Case of a University in Bandung, Indonesia. *E3s Web of Conferences*, 485, 7004. <https://doi.org/10.1051/e3sconf/202448507004>
- Gabriel, S., Liebhart-Gundacker, M., Pecher, H., Römisch, B., Überacker, G., & Wallner, J. (2023). Digitalisierung Als Treiber Von Bildungs(un-)Gerechtigkeit. *R&e-Source*, 10(3). <https://doi.org/10.53349/resource.2023.i3.a1143>
- Hamdan, F. A., Lara-Sánchez, A., & Arufe-Giráldez, V. (2023). Critical Thinking in Environmental Education Through Digital Games Among Students. *Environment and Social Psychology*, 8(2). <https://doi.org/10.54517/esp.v8i2.1725>
- Hemmer, I., Lude, A., Mainka, S., Schwarz, V., Bagoly-Simó, P., Ullrich, M., Labanino, R., & Winter, M. (2024). Sind (BNE-)Schullabels Geeignete Indikatoren, Um Die Implementierung Von Bildung Für Nachhaltige Entwicklung Ins Schulische Bildungssystem Zu Messen? Ergebnisse Eines Empirischen Projektes. *Zep-Zeitschrift Für Internationale Bildungsforschung Und Entwicklungspädagogik*, 2024(2), 4–11. <https://doi.org/10.31244/zep.2024.02.02>
- Lasino, Rukmana, A. Y., Mokodenseho, S., & Aziz, A. M. (2023). Environmental Education for Sustainable Development: A Bibliometric Review of Curriculum Design and Pedagogical Approaches. *The Eastasouth Journal of Learning and Educations*, 1(02), 65–75. <https://doi.org/10.58812/esle.v1i02.108>
- Miao, S., Meadows, M. E., Duan, Y., & Guo, F. (2022). How Does the Geography Curriculum Contribute to Education for Sustainable Development? Lessons From China and the USA. *Sustainability*, 14(17), 10637. <https://doi.org/10.3390/su141710637>
- Pedraja-Rejas, L., Rodríguez-Ponce, E., Muñoz-Fritis, C., & Laroze, D. (2023). Sustainable Development Goals and Education: A Bibliometric Review—The Case of Latin America. *Sustainability*, 15(12), 9833. <https://doi.org/10.3390/su15129833>
- Rahmawati, H., Hutagalung, F. D., Harsono, Y. T., & Qoyyimah, N. R. H. (2024). Pro-Environmental Behavior Model Among University Students. *Psymphatic Jurnal Ilmiah Psikologi*, 11(1), 9–16. <https://doi.org/10.15575/psy.v11i1.32182>



- Rueda, R. Z., Villamizar, Y. I. B., & Ardila, L. E. B. (2023). A Retrospective Approach to Pro-Environmental Behavior From Environmental Education: An Alternative From Sustainable Development. *Sustainability*, 15(6), 5291. <https://doi.org/10.3390/su15065291>
- Tinilau, S. S., Hemstock, S. L., Mercer, T. G., Hannaford, M., & Kythreotis, A. P. (2024). Environmental Stewardship in Tuvalu Formal School Education – A Policy Analysis Perspective Across Scales. <https://doi.org/10.20944/preprints202407.0518.v1>