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EDUCATING FOR THE CIRCULAR FUTURE: A BIBLIOMETRIC STUDY ON CIRCULAR ECONOMY IN EDUCATIONAL SETTINGS

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ABSTRACT

Background and Purpose: The circular economy (CE) has gained global momentum as a strategy to promote sustainability through resource efficiency and waste reduction. To instill sustainable mindsets in future generation, integrating CE in education is essential. However, a comprehensive understanding of scholarly contributions of CE in education remains limited. Therefore, the objective of this study is to map global research trends on CE in education by analyzing publication trends, influential author, leading countries and co-occurring author keywords clustering through a bibliometric study.

Methodology: A bibliometric analysis was conducted using VOSviewer software (version 1.6.18) based on data retrieved from Scopus database. A total of 1424 documents published between 2006 and July 2025 were analysed. Data collection was conducted between July 10 and 12, 2025. This study analysed publication trends, authors, institutions, countries productivity, author keyword co-occurrence and clustering.

Findings: The findings highlight a significant increase in publications, with influential authors, institutions and countries. One dominant keyword and 13 thematic clusters were identified, reflecting the growing interest and multidisciplinary nature of CE in education.

Contributions: By mapping research trajectories and key contributors, it offers a solid basis for advancing future research, guiding curriculum development, shaping education policy and strengthening CE-focused educational settings.

Keywords: Circular economy, education, sustainability, bibliometric analysis, keywords clustering.

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1.0 INTRODUCTION

Circular economy (CE) is a paradigm shift that challenges conventional linear model (take-make-dispose) by promoting resource-efficient, regenerative systems (Hossain et al., 2024; Geissdoerfer et al., 2017; Kirchherr et al., 2017). In recent years, CE has expanded beyond its traditional environmental and economic focus to increasingly incorporate social, educational and digital dimension (Mies & Gold, 2021; Sassanelli et al., 2023; Serrano-Bedia & Perez-Perez, 2022), reflecting a systemic transition in knowledge, values and behaviors (Kirchherr et al., 2023; Tiippana-Usvasalo et al., 2023). Alongside this shift, emerging research highlights on growing role of digital transformation, Industry 4.0 technologies and sustainability-oriented pedagogy in enabling CE practices within educational context (Rejeb et al., 2022; Hossain et al., 2024). Consequently, education is now widely recognized as a central driver for cultivating competencies and sustainable behaviors among future generations (Renfors, 2024; Khajuria, 2025)

Despite the increasing policy attention and industrial implementation of CE, research on CE in education remains relatively underexplored. CE scholars have traditionally been dominated by engineering and industrial (Okorie et al., 2018) with limited emphasis on pedagogical integration. Many education systems are still in the early stages of embedding CE into curriculum, resulting in uneven scholarly attention across regions and disciplines (Renfors, 2024). These factors contribute to the limited understanding of how CE is currently being conceptualized, implemented and studied within educational settings. Therefore, it is necessary to understand how CE is integrated into educational settings globally by examining the volume of publications, the thematic patterns, epistemological stances and collaborative networks that support CE in education. In order to map the intellectual structure of CE and education and to reveal the dynamic in the international research trends, bibliometric analysis provides a strong methodological lens through which to trace these developments (Donthu et al., 2021; Aziz et al., 2024).

This study aims to conduct bibliometric analysis of CE in the educational settings published and indexed in Scopus from 2006 to July, 2025 (as of writing) to gain a holistic picture on what research has been done in the studied topic so far. Overall, this study aims to explore the research trends of CE in education through the following research questions:

1) What are the current trends of publications concerning CE and education in literature?
2) Which are the most productive and influential authors, institutions and countries on CE and education studies?
3) Which are the most cited articles on CE and education studies?
4) What keywords are frequently used in CE and education studies?
5) What are the keywords co-occurrence clusters identified and how do these clusters reveal about the underexplored areas in CE within educational studies?

2.0 LITERATURE REVIEW

2.1 Circular Economy (CE)

Various definitions of CE exist in literature. Nußholz (2017) defined CE as a paradigm that suggests a redesign of the current linear economic system, largely based on linear resource flows, towards closed-loop resource flows that can preserve the embedded environmental and economic value in products over time. Geissdoerfer et al. (2017) referred CE as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing,

and narrowing material and energy loops. Other studies refer CE as an economic model aimed at replacing linear production with regenerative systems (D'Amato et al., 2017; Suchek et al., 2021; Ahmad et al., 2022). At its core, CE seeks to close material loops, reduce environmental degradation, and foster economic systems that minimize waste while maximizing resource efficiency (Elroi et al., 2023; Geissdoerfer et al., 2017; Kirchherr et al., 2017). To achieve these goals, CE adopts practical strategies such as reuse, repair, recycling, and extending product life cycles, all of which are designed to mitigate environmental impacts (Milios, 2021; Timm et al., 2023; Spreafico & Landi, 2022).

2.2 Education as a Lever for Circular Transition

Education is essential to the broad acceptance of CE. Promoting CE necessitates educational initiatives at every level, starting from preschool to higher education and lifetime learning, involving people from all phases of life (Tiippana-Usvasalo et al., 2023). This all-encompassing educational initiative is crucial for bringing the change from linear economy to CE as it modifies the production and consumption patterns to more effectively address environmental issues. In line with this, the United Nations Sustainable Development Goals (SDGs) place a strong emphasis on the vital role that education plays in CE agenda. Rather than functioning only as dissemination platform, education is increasingly positioned as the mechanism through which CE principles are translated to long term sustainability actions.

2.3 Emerging Studies on Circular Economy in Education

Studies on CE in education is emerging but remains geographically and thematically uneven. Table 1shows a summary of selected studies on CE in education across various educational levels and context. Most of the studies originated from Europe, with limited representation from other regions. These studies span different educational levels, including primary, secondary and higher education.

Table 1: Summary of emerging studies

Studies	Authors	Level	Context
Education for sustainability: The role of reuse and conversion concepts for youth	Șoica et al. (2024)	Primary and secondary school	Explore the integration of reuse and conversion concepts to promote CE and sustainable practices.
ROB-E – Swarm Robotics for Education in Circular Economy	Schranz et al. (2022)	Primary and secondary school	Hands-on robotics workshops teaching CE principles.
Educating on Circular Economy and DIY materials: How to Introduce these Concepts in Primary School Students?	Alarcón et al. (2019)	Primary schools	Raising awareness on CE through DIY materials made from waste.
Integrating circular economy into STEM education: A promising pathway toward circular citizenship development	Nguyen (2023)	Secondary schools	Promoting sustainable development by integrating CE in STEM education.
Circular economy, sustainability and teacher training in a higher education institution	Bugallo-Rodríguez & Vega-Marcote (2020)	Higher institution	Designed activities to improve attitudes and actions towards reducing daily impact and promoting CE.
Education for the circular economy in higher education: an overview of the current state	Renfors (2024)	Higher institution	Incorporating demand side into courses by including CE to promote systems thinking.

2.4 Past Bibliometric Analyses on Circular Economy Studies

Recent bibliometric studies have highlighted the rapid growth and interdisciplinary nature of CE research. For example, Uwuigbe et al. (2024) reviewed CE studies in emerging economies from 2010 to 2024, revealing a sharp rise in publications since 2019. Key research themes included sustainability, waste management, and innovative business models, with strong contributions from India, the UK, and China. The study also emphasized the need for interdisciplinary collaboration and attention to regional contexts. Similarly, Dominko et al. (2022) observed that CE research has largely focused on theoretical and technological aspects, calling for more action-oriented studies that involve stakeholders and explore practical implementation in sustainable supply chains, waste management, and business model innovation.

Gonzalez et al. (2023) analyzed articles from 2013 to 2022 and identified important connections between CE and areas such as smart cities, sustainable development, waste management, and climate change, highlighting growing interdisciplinary links among urban planning, engineering, economics, and environmental science. In the tourism sector, Şahin et al. (2024) reported a notable increase in CE research since 2015, with Italy, Spain, and China as

leading contributors, focusing on waste management and recycling. Kabil et al. (2024) similarly emphasized the growing adoption of CE principles in tourism, noting that nearly all aspects of tourism development and management are receptive to circular approaches.

Beyond these sectors, sustainability in education has also received increasing scholarly attention. Dönmez (2024) noted a rising number of publications on sustainability in education, with a shift from traditional environmental education toward sustainable education influenced by the Sustainable Development Goals, led mainly by the UK, Germany, and the US. Alongside this, Hamid et al. (2024) highlighted the growing integration of circular economy and sustainable technology in Technical and Vocational Education and Training (TVET), reflecting a significant rise in publications over the past decade and underscoring the relevance of CE principles in vocational education.

Taken together, these studies demonstrate the expanding global interest in CE, its practical applications across sectors, and its integration into educational frameworks. While previous bibliometric studies have mapped CE research in general, their focus has predominantly varied across different contexts, particularly within businesses and organizations. In contrast, research on CE within educational settings remains in its early stages, is largely concentrated in Europe, and exhibits considerable variation in scope. A comprehensive understanding of how CE is embedded in educational contexts is therefore still lacking. Examining publication trends, leading authors, institutions, and countries, along with prevalent keywords, offers a valuable means to elucidate CE integration in education through a bibliometric lens.

3.0 RESEARCH DESIGN

This study employed bibliometric analysis to investigate trends within the academic literature concerning the CE in education. Bibliometric analysis facilitates the examination of external aspects of scientific publications, allowing the analysis of research status, emerging directions and development trends in order to predict future academic trajectories (Wang & Su, 2020; Jiang et al., 2019). According to Meşe (2023), bibliometric analysis is widely used in many fields, including education and offers a thorough picture of publication trends and cooperative networks. Specialized software tools, VOSviewer (v1.6.18) were employed to process the dataset and construct visualizations of bibliometric networks. In the present study, the dataset was sourced exclusively from the Scopus database for its broad multidisciplinary coverage and rich bibliometric metadata suitable for network and co-occurrence analyses (Baas et al., 2020).

3.1 Data Extraction

This study analysed publication trends within the academic literature on CE in education. Data collection from the Scopus database took place between 10th and 12th July 2025, covering publications from 2006 to 12th July 2025. To ensure comprehensive coverage of CE-related education research, the search string included terms representing different learning contexts, such as “education,” “classroom,” “school,” “curriculum,” “training,” “teaching,” “higher education,” and “learning.” The search was performed in the title, abstract, and keywords fields (TITLE-ABS-KEY) to maximize retrieval of relevant documents. The final search string was: TITLE-ABS-KEY ("circular economy" AND ("education" OR "classroom" OR "school" OR "curriculum" OR "training" OR "teaching" OR "higher education" OR "learning")). This approach enabled the inclusion of studies across multiple educational levels, including formal schooling, teacher training, and higher education. The search yielded 1,481 articles globally. After exporting the dataset, 57 non-English publications were removed, resulting in a final corpus of 1,424 documents

for analysis. The data were exported in .csv format and processed using VOSviewer v1.6.18 for mapping and visualization of bibliometric networks. Figure 1 illustrates the overall procedure of data extraction and processing.

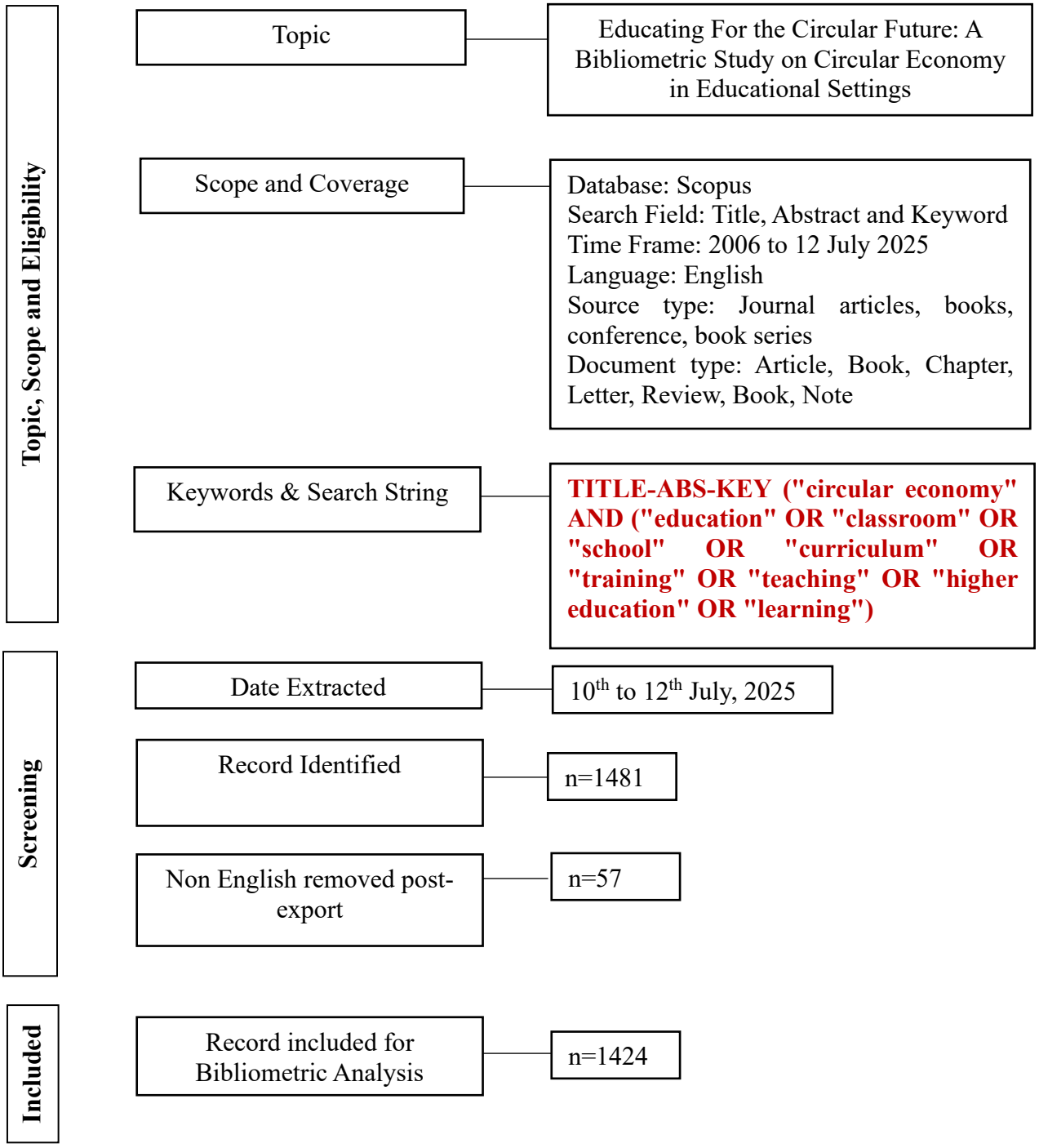

Figure 1: Data extraction procedure

3.2 Data Cleaning

Before analysis, the dataset underwent data cleaning. Data cleaning involved several steps to ensure accuracy and prevent double counting (Azizan, 2024) Duplicate publications were identified using DOI and fuzzy title matching (90% similarity threshold), with the most complete record retained. Author names and institutional affiliations were harmonized to unify variants, and ORCID identifiers were used where available to reduce ambiguity. Multi-author and multi-country publications were handled using fractional counting. Keywords were standardized by merging singular and plural forms, correcting spelling errors, harmonizing hyphenation and case and expanding acronyms.

3.3 Network Analysis Parameters

Co-authorship and keyword networks were analyzed using VOSviewer v1.6.18. The full counting method was applied, giving equal weight to each occurrence, and a minimum keyword occurrence threshold of 5 was set (Azizan, 2023; Ong et al., 2025). Link strengths were normalized using association strength, and clusters were identified with a modularity-based algorithm using the LinLog option (Azizan, 2024). To maintain accurate clustering and consistent terminology, a thesaurus file was employed to merge synonyms, remove stop-terms, and standardize keywords for circular economy (CE), education, and sustainability-related concepts (Azizan, 2023, 2024). Controlled synonyms included CE terms (‘circular economy’, ‘circular business model’), education-related terms (‘education’, ‘teacher training’, ‘project-based learning’), and sustainability anchors (‘sustainable development’, ‘SDGs’, ‘life cycle assessment’). For example, the term “Sustainability development” was also corrected to “Sustainable development,” ensuring that all keyword counts reflected the harmonized terminology. This standardization facilitated consistent keyword co-occurrence mapping and reliable cluster formation.

4.0 ANALYSIS

This study utilized two common bibliometric analysis approaches: performance analysis and science mapping (Donthu et al., 2021). Performance analysis in bibliometric studies evaluates the impact of academic entities (articles, researchers, journals) using quantitative metrics (Krithika & Vasantha, 2023). It identifies top contributors, trending keywords, and research opportunities in a field (Krithika & Vasantha, 2023; Hanifa et al., 2023). Common bibliometric indicators used in performance analysis include publication numbers, citation numbers, h-index and journal impact factors. In this study, the source and type of documents, publications by year, most influential authors, institutions and countries and most cited articles were reported. These findings underscore the importance of determining scholarly impact and productivity.

On the other hands, science mapping combines quantitative analysis, classification, and visualization to identify relationships between bibliographic objects (Swami et al., 2021; Andersen & Swami, 2021). In this study, science mapping was utilized to perform keyword analysis using VOSviewer software. While there are various techniques for science mapping, this study utilized science mapping analysis to establish keywords co-occurrence clusters. This analysis treats keywords as nodes and their co-occurrence as links, revealing knowledge structures and evolving research interests (Ozek et al., 2022; Yuan et al., 2022).

4.1 Performance Analysis

4.1.1 RQ1- Current trends of publications concerning CE and education

Documents Profiles

Table 2: Document type

Document Type	Total Publication (TP)	Percentage
Article	728	51.1
Conference Paper	267	18.8
Book Chapter	190	13.3
Review	119	8.4
Conference Review	55	3.9
Book	38	2.7
Editorial	11	0.8
Erratum	5	0.4
Note	5	0.4
Short Survey	4	0.3
Data Paper	1	0.1
Letter	1	0.1
Total	**1424**	**100**

Table 2 shows the distribution of publications according to document type. It shows that 728 (51.1%) of the total documents were articles, 267 (18.8%) were conference papers, 190 (13.3%) were book chapters, 119 (8.4%) were reviews, 55 (3.9%) were conference reviews, while 38 (2.7%) were books. The analysed documents also included 11(0.8%) editorials, 5 erratum and 5 notes (0.4%), 4 (0.3%) short surveys, one data paper and one letter.

Source Type

Table 3: Source type

Source Type	Total Publication (TP)	Percentage
Journal	872	61.2
Conference Proceeding	226	15.9
Book	177	12.4
Book Series	147	10.3
Trade Journal	2	0.2
Total	**1424**	**100**

Table 3 shows the source type identified in this study. Journals, were the predominant source, accounting for 872 (61.2%), followed by conference proceeding (n=226; 15.9%), book (n=177; 12.4%), book series (n=147; 10.3%) and trade journal (n=2; 0.2%).

Publication Trends

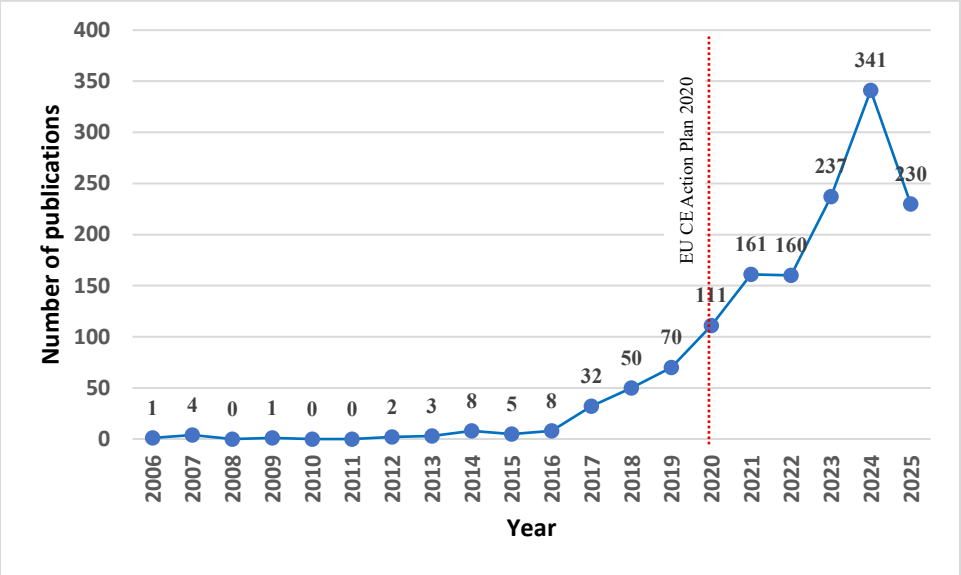

Figure 2: Trends in publication of research articles on CE in education from 2006 to 2025

Table 4: Total number of publications produced per year

Year	Total number of publications	Percentage
2025	230	16.15
2024	341	23.94
2023	237	16.64
2022	160	11.23
2021	161	11.30
2020	111	7.79
2019	70	4.91
2018	50	3.51
2017	32	2.25
2016	8	0.56
2015	5	0.35
2014	8	0.56
2013	3	0.21
2012	2	0.14
2009	1	0.09
2007	4	0.28
2006	1	0.09

Figure 2 and Table 4 illustrate the trends in the number of publications produced on CE in education per year. Results show that only 32 articles were published between 2006 to 2016. In 2017, the number of published articles on CE saw a significant increase, with 32 articles. From 2017 to 2025, the numbers increased gradually, about 97.72%, reflecting that researchers started to recognize circular economy in education. A consistent and rapid growth in publications underscored an escalating recognition of the integration of circular economy in education globally.

4.1.2 RQ 2- Most Productive and Influential Authors, Institutions and Countries on CE and Education

Most Productive and Influential Authors

Table 5: Most influential authors

Authors	TP	Percentage	Affliation	Country	TC
Kopnina, H.	13	0.91	University of Amsterdam	The Netherlands	719
Zorpas, A.A.	10	0.70	Open University of Cyprus	Cyprus	475
Sehnem, S.	9	0.63	Universidade do Oeste de Santa Catarina	Brazil	445
Shooshtarian, S.	8	0.56	RMIT University	Australia	130
Zaman, A.	8	0.50	Curtin University	Australia	116
Acerbi, F.	7	0.50	Politecnico di Milano	Italy	35
Maqsood, T.	7	0.50	Curtin University	Australia	130
Ramakrishna, S.	7	0.50	National University of Singapore	Singapore	285
Sassanelli, C.	7	0.50	Politecnico di Bari	Italy	38
Terzi, S.	7	0.50	Politecnico di Milano	Italy	26

Table 5 presents the most influential authors in the field. The analysis reveals that the most influential author is Kopnina, H., affiliated with the University of Amsterdam, Netherlands, with thirteen publications. This is followed by Zorpas, A.A. from the Open University of Cyprus, Cyprus, with ten publications, and Sehnem, S. from the Universidade do Oeste de Santa Catarina, Brazil, with nine publications. Further examination indicates that the six publications by Terzi, S. are the same as those by Sassanelli, C., and similarly, four publications are jointly attributed to Acerbi, F. Additionally, Shooshtarian, S., Zaman, A., and Maqsood, T. each contributed to the same four publications. Finally, seven publications were contributed by Ramakrishna, S. These findings reflect the presence of established scholars and active research groups within the CE studies. For instance, authors such as Kopnina, H. and Zorpas, A.A have long-standing engagement in sustainability and environmental education, enabling consistent output and high citation visibility.

Top Contributing Institutions

Table 6: Top contributing institutions

Institutions	Country	TP	Percentage
Delft University of Technology	The Netherlands	27	1.89
RMIT University	Australia	20	1.40
Politecnico di Milano	Itali	16	1.12
Universidade de Lisboa	Portugal	16	1.12
Aalborg University	Denmark	15	1.05
CNRS Centre National de la Recherche Scientifique	France	13	0.91
Universidad Politécnica de Madrid	Spain	12	0.84
Universitat Politècnica de Catalunya	Spain	11	0.77
National University of Singapore	Singapore	11	0.77
Curtin University	Australia	11	0.77

Table 6 shows that 10.64% of the total publications were published by the top ten contributing institution, with Delft University of Technology to be on the top of the list. RMIT University is on the second rank, while Politecnico di Milano and Universidade de Lisboa sharing the third rank. This is followed by Aalborg University, CNRS Centre National de la Recherche Scientifique, Universidad Politécnica de Madrid, Universitat Politècnica de Catalunya, National University of Singapore and Curtin University. Seven of these countries are from Europe, two from Australia and one is from Asia. The dominance of European institutions reflects the regions' dedicated research centres, labs or interdisciplinary platforms that CE studies. This enables continuous CE experimentation, joint industry–university projects, and funded research programmes.

Top Contributing Countries

Table 7: Top contributing countries

Countries	TP	Percentage
United Kingdom	177	12.43
Italy	130	9.13
Spain	118	8.29
United States	109	7.65
Portugal	80	5.62
Germany	74	5.20
Netherlands	71	4.99
China	70	4.92
India	69	4.85
Australia	68	4.76

Table 7 shows that 67.84% of the total publications were contributed by the top ten contributing countries. On top of the list include the United Kingdom (12.43%), Italy (9.13%), and Spain (8.29%). This is followed by the United States (7.65%), Portugal (5.62%), Germany (5.20%), the Netherlands (4.99%), China (4.92%), India (4.85%) and Australia (4.76%). Notably, six countries were from Europe, two from Asia, one from US and Australia respectively. The dominance of European countries further reflects strong policy support and fundings for CE initiatives, which drive higher research output from the countries.

4.1.3 RQ 3- Most Cited Articles

Highly Cited Documents

Table 8: Most cited papers

Title	TC	TC/Year
Green, circular, bio economy: A comparative analysis	766	40.3
Carbon peak and neutrality in China	495	26.1
Operational principles of circular economy	453	23.8
Unlocking value for circular economy via AM	410	21.6
Implementation of green chemistry principles	392	20.6
Education for the future? Critical evaluation	344	18.1
Circular economy in solid waste management	342	18
Skills for sustainable circular economy	334	17.6
Barriers to smart waste management	334	17.6
Critical framework for UNWTO's tourism agenda	311	16.4

Table 8 shows the most cited articles. On top of the list is *Green, circular, bio economy: A comparative analysis* by D'Amato et al. (2017) with 766 citations and an average of 40.3 citations per year. This article offers a comparative framework for understanding CE that are increasingly being incorporated into curricula, particularly in environmental education and education for sustainable development (ESD). The next most cited article is *Carbon peak and neutrality in China* by Wang et al. (2021) with 495 citations and 26.1 citation per year. The article discusses the implementation path and the prospect of national level carbon peak and neutralization in China, which implications is relevant in educational contexts, particularly in climate change education. Notably, these articles provide insights of CE in the educational settings by guiding curriculum design, skill development and evidence-based integration of CE into education and ensuring sustainable practices in industry and society.

4.2 Science Mapping

4.2.1 RQ 4 – Frequently Used Keywords

Table 9: Most frequently used keywords

Keywords	TP	Percentage
Circular economy	753	52.88
Sustainability	213	14.96
Sustainable development	**102**	**7.16**
Education	87	6.11
Recycling	59	4.14
Waste management	59	4.14
Higher education	40	2.81
Sustainable development goals	35	2.46
Design education	26	1.83
Climate change	28	1.97

Table 9 shows the frequency of different author keywords used. It reveals that the most frequently used keyword is "circular economy", appearing in 52.88% of the papers. The keyword "sustainability" present in 14.96%, followed by "sustainable development" in 7.16% and "sustainable development goals" in 2.46% of the total publications. This consistency in the keywords highlights the ongoing relevance of sustainability concepts in CE. Keywords such as "education" (6.11%), "higher education" (2.81%) and "design education" (1.83%) highlights the recognition of education as a platform to integrate CE. "Recycling" and "Waste management" both appear in 4.14% of the total publications, reflecting a focus on CE principle in eliminating waste and pollution (Principle 1). The keyword "climate change" that appears in 1.97% of the total publications shows the priority of CE over solving environmental phenomena.

4.2.2 RQ 5 –Keyword Co-Occurrence Cluster

Authors' keywords were exported from Scopus and mapped using VOSviewer v1.6.18. The power of connection amongst keywords is represented through attributes such as colors, scale of the circle, font, and thickness of the connecting lines (Aziz et al., 2024). A total of 13 clusters were revealed. Cluster 1 in red highlights sustainable policies (e.g., in education, governance and urban systems). Cluster 2 in green highlights the role of digital transformation (e.g., artificial intelligence, machine learning) within the context of education and sustainability. Cluster 3 in blue addresses the behavioral aspects. This cluster includes waste management strategies such as recycling and

eco designs. Meanwhile, Cluster 4 in yellow explores the environmental impact such as climate change, health issues (Covid 19), construction and energy efficiency. Cluster 5 in purple emphasizes the circularity of CE (e.g., cradle to cradle). Cluster 6 in turquoise connects the design concepts of CE (e.g., circular design, design education, design thinking). Cluster 7 in orange delves into economy and entrepreneurship. Cluster 8 in brown highlight the variables of behavior such as consumer behavior, pro environmental behavior and attitude. Cluster 9 in pink focuses on manufacturing aspects through eco design and eco-innovation. Cluster 10 in peach captures regional and CE perspectives especially in Australia. Cluster 11 in light green focuses on pedagogical strategies in higher education for sustainability. Cluster 12 in light blue reflects the role of human capital in the environmental efforts. Finally, Cluster 13 in light yellow reflects the methodological approach through systemic literature reviews in CE studies.

The 13 clusters collectively illustrate that circular economy (CE) research in educational studies is closely aligned with the Sustainable Development Goals (SDGs). Clusters 1 and 4 highlight connections to education reforms and broader sustainability objectives, particularly SDG 4 (Quality Education), SDG 11 (Sustainable Cities), SDG 12 (Responsible Consumption), and SDG 13 (Climate Action). Cluster 2 emphasizes the integration of digital tools, linking to SDG 4 and SDG 9 (Industry, Innovation, and Infrastructure). Clusters 3 and 8 relate to SDG 12 and SDG 13, reflecting behavioral and consumption-focused aspects of CE. Clusters 5 and 6 connect to SDG 4 and SDG 12 through design, pedagogy, and circularity principles. Clusters 7 and 9 are associated with SDG 8 (Decent Work and Economic Growth) and SDG 9, highlighting CE in entrepreneurship and manufacturing. Cluster 10 links to SDG 11 and SDG 12, while Clusters 11, 12, and 13 are primarily connected to SDG 4. Overall, these findings indicate that CE in educational settings is highly related to SDG 4, underscoring the pivotal role of education in promoting circular economy principles and sustainable development. Figure 3 and Table 10 show the science mapping and keywords co-occurrence cluster.

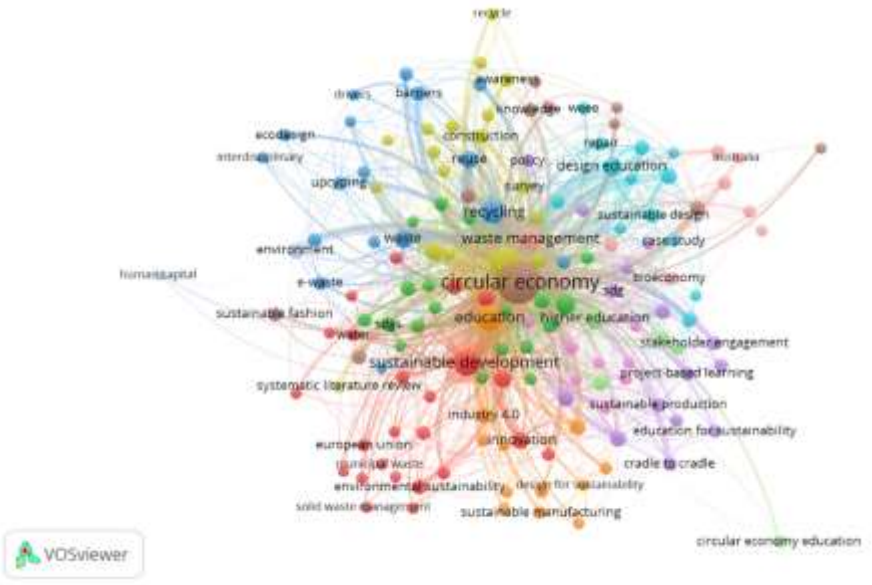

Figure 3: Science mapping of authors keywords co-occurrence

Table 10: Keyword co-occurrence clusters

Cluster 1 (Red)	**Cluster 2 (Green)**	**Cluster 3 (Blue)**
Agriculture	Artificial Intelligence	Barriers
Circular economy (ce)	Bibliometric Analysis	Consumer behavior
Economic growth	China	Drivers
Education for Sustainable	Cleaner Production	e-waste
Development (ESD)	Corporate Social Responses	ecodesign
Energy	Curriculum	global south
Environmental Awareness	Developing countries	interdisciplinary
Environmental Education	Digital transformation	plastics
Environmental sustainability	Environmental Impact	recycling
European Union	Higher Education Institute	remanufacturing
Food Security	Industrial Ecology	reuse
Food waste	Machine learning	reverse logistics
Governance	Renewable energy	solid waste
Innovation	SDGs	technology
Municipal waste	Smart cities	upcycling
Panel Data	Stakeholders	waste
Smart cities	Sustainable Development	zero waste
Social Innovation	Sustainable Tourism	
Solid waste management	TransitionArtificial Intelligence	
Sustainability Education	Bibliometric Analysis	
Sustainable Development	China	
Sustainable Development Goals	Cleaner Production	
(SDGs)	Corporate Social Responses	
Urban Argriculture	Curriculum	
Wastewater	Developing countries	
Water	Digital transformation	
	Environmental Impact	
	Higher Education Institute	
	Industrial Ecology	
	Machine learning	
	Renewable energy	
	SDGs	
	Smart cities	
	Stakeholders	
	Sustainable Development	
	Sustainable Tourism	
	Transition	

Cluster 4 (Yellow)	**Cluster 5 (Purple)**	**Cluster 6 (Turquoise)**
Awareness	Buildings	Business model
Blockchain	Cradle to cradle	Case study
Built environment	Education for sustainability	Circular design
Carbon footprint	Green chemistry	Competencies
Climate change	Industry	Design education
Construction	LCA	Design thinking
Construction industry	life cycle assessment	Pedagogy
Covid-19	policy	Product design
Energy efficiency	project-based learning	Repair
Greenhouse gas emission	sdg	Sustainable design
Plastic pollution	stakeholder engagement	Systems thinking
Recycle	sustainable consumption	Transformation
Schools	sustainable production	weee
Survey	university	
Sustainability		

Sustainable constructions Systems dynamics		
Cluster 7 (Orange)	**Cluster 8 (Brown)**	**Cluster 9 (Pink)**
Business model Circular business model Design for sustainability Digital economy Digitalization Education Entrepreneurship Game-based learning Industry 4.0 Simulation Sustainable consumption Sustainable manufacturing	Attitudes Circular economy Circularity Consumer behavior Environmental management Knowledge Pro-environmental behavior Public awareness Resource efficiency Sustainable fashion Willingness to pay	Circular business model Eco-design Eco-innovation Engineering Industry 5.0 Manufacturing Skills Teaching
Cluster 10 (Peach)	**Cluster 11 (Light Green)**	**Cluster 12 (Light Blue)**
Australia Bioeconomy Circular bioeconomy Construction and demolition Literature review Municipal solid waste Training Waste management	Circular economy education Educational innovation Engineering education Experiential learning Higher education	Environment Human Capital
		Cluster 13 (Light Yelllow)
		Systemic Literature Review

Table 11 synthesizes the 13 keywords co-occurrence clusters, highlighting their connections to the Sustainable Development Goals, relevant to CE and practical implications for educations.

Table 11: Keyword co-occurrence clusters – Links to SDGs, CE practices/policy, and educational implications

Cluster	Theme	SDGs	CE Practices/Policies	Implications for Education
1	Sustainable policies	4,11,12,13	Governance, municipal waste, urban sustainability	Integrate policy literacy, sustainability projects, ESD into curriculum
2	Digital transformation	4,9	AI/ML applications, digital tools for CE	Teach digital skills for CE, use AI/ML tools in learning activities
3	Behavioral aspects	12,13	Recycling, circular consumption, pro-environmental behavior	Embed behavior-change modules, awareness campaigns, project-based learning
4	Environmental impacts	4,11,12,13	Waste management, energy efficiency, climate mitigation	Include environmental impact assessment exercises, climate education
5	Circularity principles	4,12	Cradle-to-cradle, life-cycle assessment, circular design	Integrate design-thinking and life-cycle thinking into courses and assignments
6	CE design & pedagogy	4,12	CE design thinking, sustainable product design, repair	Use hands-on labs, prototyping, and circular design projects in teaching
7	Economy & entrepreneurship	8,9	Circular business models, green entrepreneurship, eco-innovation	Teach CE entrepreneurship, case studies, business-model simulations
8	Behavioral variables	12,13	Consumer behavior, public awareness, resource efficiency	Embed reflective learning, consumer behavior analysis, sustainability awareness activities
9	Manufacturing & innovation	8,9	Sustainable manufacturing, eco-design, Industry 5.0 practices	Include CE manufacturing case studies, eco-innovation projects, engineering labs
10	Regional CE perspectives	11,12	Regional CE policy, bioeconomy, construction waste management	Teach region-specific CE policies, case comparisons, local sustainability projects
11	Pedagogy in higher education	4	Experiential CE learning, higher education curricula	Incorporate project-based learning, experiential labs, and curriculum innovations
12	Human capital	4	CE skills development, workforce capacity building	Include CE skill-building workshops, workforce development modules
13	Methodological approaches	4	Evidence-based CE policy, research literacy	Teach systematic literature review, research methods, and evidence-based CE projects

5.0 DISCUSSION

The first research question explores the current trends of publications concerning CE and education in literature. It has been revealed that the studies on CE have increased drastically since 2017, reflecting an escalating interest of CE in the educational settings. This trend aligns with previous bibliometric studies, such as Uwuigbe et al. (2024), who reported a sharp rise in CE publications since 2019 in emerging economies, and Dominko et al. (2022), who observed rapid growth of CE research focusing on theoretical and technological aspects. However, while publication numbers are increasing, the focus appears uneven across regions, with Europe dominating the research. Various efforts have also taken to embed CE in educational settings. For instance, Trevisan et al. (2025) proposed a framework for fostering CE skills in higher education and vocational training, while Renfors (2024) examined characteristics of education for CE. These studies demonstrate practical approaches to integrating CE into curriculum, yet most examples originate from European or developed country contexts, highlighting a gap in global inclusivity.

In relation to the second research question, the most productive and influential authors are Kopnina, H from University of Amsterdam, Netherlands; Zorpas, A.A from Open University of Cyprus, Cyprus and Sehnem, S from Universidade do Oeste de Santa Catarina, Brazil. The United Kingdom, Italy and Spain were revealed to be the most contributing countries. Delft University of Technology, RMIT University and Politecnico di Milano were the top contributing institutions. This European dominance suggests that policy support and regional initiatives may drive research productivity, but it also raises concerns about the underrepresentation of other regions in CE education research, confirming observations from prior studies (Uwuigbe et al., 2024; Hamid et al., 2024).

The third research question revealed that the most cited article is *Green, circular, bio economy: A comparative analysis* by D'Amato et al. (2017) with 766 citations. This article comprehensively analyse the diversity within and between CE, green economy and bioeconomy through a bibliometric review. It is revealed that CE and bioeconomy focus on resource while green economy acknowledges the underpinning role of all ecological processes. This is anticipated to highlight the integration of CE in the educational settings that should centers on resource-based teaching and learning, which aligns with the emphasis identified in this article.

The fourth research question revealed that among the most used keywords include circular economy, sustainability and sustainable development. The prominence of "circular economy" aligns with prior studies (Uwuigbe et al., 2024; Şahin et al., 2024), reflecting its central role in addressing global sustainability challenges. The analysis shows that "circular economy" is highly connected to most of the keywords shown in the database. This suggests that authors select this term to enhance its visibility and relevance of their research.

The final research question revealed 13 keywords clusters. Cluster 1: sustainability policies, Cluster 2: digital transformation, Cluster 3: behavioral aspects, Cluster 4: environmental impacts, Cluster 5: life cycle thinking, Cluster 6: entrepreneurship, Cluster 7: consumers attitudes, Cluster 8: engineering innovations, Cluster 9: regional perspectives, Cluster 10: pedagogical innovations, Cluster 11: human capital, Cluster 12: methodological development and Cluster 13: systemic literature review. These clusters indicate that CE education research spans policy, technological, behavioral, and pedagogical dimensions. Notably, sustainability policies and digital transformation are highly emphasized, whereas behavioral aspects, regional perspectives, and pedagogical innovations appear less prominent, pointing to potential gaps. For educators, curriculum developers, and policymakers, this suggests that while technical and policy content is

well-covered, there is a need to strengthen focus on student behavior, inclusive teaching approaches and pedagogies, and global applicability.

6.0 CONCLUSION

The findings of this bibliometric study reveal a progressively growing but still relatively limited body of literature on circular economy and education from 2006 to 2025. It shows that while interest in CE education has grown significantly since 2017, the field remains relatively limited and geographically concentrated among a limited set of countries and institutions. Majority of the publications were from Europe, with comparatively fewer contributions from Asia. Influential authors have made significant contribution in the literature on CE in education, with the European institutions leading to the majority of the publication outputs. This highlights the need for more globally inclusive research that considers diverse regional and cultural contexts, which could inform the development of universally applicable CE educational strategies.

The mapping of keywords and research clusters reveals that CE education encompasses multidimensional themes, including sustainable policies, digital transformations and behavioral dimensions. However, certain areas, particularly those related to innovative teaching methods and interdisciplinary curriculum, remain underexplored. This gap provides a foundation for designing evidence-based pedagogical approaches that actively integrate CE principles at various educational levels.

Practically, these findings can guide curriculum developers, educators and policymakers in structuring CE courses, fostering interdisciplinary approaches and prioritizing research that connect theoretical frameworks of CE with outcomes focusing on teaching and learning. Future research should focus on empirical studies of teaching strategies, curriculum interventions as well as evaluating the effectiveness of CE in education in various educational settings. Such studies can advance both theory and practice of CE in education, ultimately supporting its integration into global sustainability agendas.

7.0 LIMITATION OF THE STUDY

Among the limitations of this study is the data output obtained from Scopus database may not encompass all articles related to CE in education as the search field only include article title, abstract and keywords. Additionally, this study did not include grey literature, which may limit the comprehensiveness of the findings. This study also only analysed the data obtained from Scopus databases within the study time frame. Therefore, future research is advised to extract data from multiple databases, such as Web of Science and Google Scholar, and consider including grey literature or full-text searches to improve the scope of the study. Another limitation is that the document extraction was based on limited search string. This restricted search string might have caused some relevant articles to be missed out due to the different terms. Finally, the removal of non-English journals and articles necessarily resulted in a bias favoring publications published in Scopus-indexed journals from English-speaking nations. As a result, this analysis may have overlooked some prominent figures and studies contextualized in non-English speaking regions.

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