JTPED

Journal of Technological Pedagogy and Educational Development
Vol. 1, No. 2, 2024, pp. 36-52
https://ejournal.jtped.org/ojs/index.php/jtped

Trends in Culturally Responsive Teaching for Science Education: A Bibliometric Analysis

Hajidah Salsabila Allissa Fitri [a,1,*], Elysa Putri Agustin [b,2], Sumalee Chuchai [c,3], Rasamimanana Joronavalona [d,4], Salman Ali [e,5]

[a] Department of Chemistry Education, Universitas Negeri Yogyakarta, Indonesia
[b] School of Metallurgy, Northeastern University, China
[c] Department of Curriculum and Instruction, Srinakharinwirot University, Thailand
[d] Department of Animal Physiology, University of Antananarivo, Madagascar
[e] Department of Pharmacy, Hajvery University, Pakistan
[1] hajidahsalsabila.2023@student.uny.ac.id; [2] putriagustinelysa@gmail.com; [3] sumaleech@g.swu.ac.th;
[4] joronavalonachemist@gmail.com; [5] salmanali11196@gmail.com
* Corresponding Author

ARTICLE INFO

Article history
Received June 09, 2025
Revised July 14, 2025
Accepted July 20, 2025

Keywords
Culturally Responsive Teaching; Science Learning; Education; Inclusive Pedagogy; Bibliometric Analysis

ABSTRACT

In the evolving landscape of science education, Culturally Responsive Teaching (CRT) has emerged as a vital pedagogical framework for promoting equity, inclusivity, and relevance. This study presents a comprehensive bibliometric analysis of global research trends and conceptual developments in CRT within science education. Utilizing data from the Scopus database and analyzed through the Biblioshiny platform, the study maps 157 peer-reviewed journal articles published between 2008 and 2025. The analysis addresses four key research questions related to publication trends, influential contributors, thematic structures, and research gaps. Findings reveal a sharp increase in scholarly attention to CRT since 2017, with a notable publication surge in 2024. The United States leads in both publication volume and international collaboration, while other countries such as Australia, Canada, and Nigeria show emerging engagement. Thematic mapping and keyword co-occurrence analysis uncover five major clusters, including science education, STEM and computing equity, culturally sustaining pedagogy, indigenous knowledge, and critical race theory. Despite growing interdisciplinary integration, gaps persist in areas such as equity in data science, culturally sustaining practices, and critical pedagogies. The study also identifies a concentration of thought leadership among a small group of scholars and institutions, highlighting the need for greater authorship diversity and geographic representation. Thematic and conceptual analyses emphasize the importance of teacher professional development, interdisciplinary approaches, and technology integration in advancing CRT practices. This bibliometric mapping contributes to a clearer understanding of CRT's evolution and current landscape in science education. Beyond academic insights, the findings hold practical relevance for educators and policymakers. They can inform curriculum design, teacher professional development programs, and equity-focused education policies aimed at fostering culturally responsive, globally inclusive, and future-ready science education systems aligned with the values of Education 4.0.

https://doi.org/10.59247/jtped.v1i2.13

1. Introduction

In recent decades, increasing global awareness of educational equity and cultural inclusiveness has prompted a growing interest in culturally responsive teaching (CRT) as a pedagogical approach [1], [2], [3]. CRT emphasizes the recognition of students' cultural backgrounds as integral to the learning process, aiming to foster more equitable, relevant, and engaging educational experiences [4], [5]. In science education, where abstract concepts and standardized curricula often dominate, the implementation of CRT becomes particularly critical [6], [7], [8]. It offers a pathway to connect scientific knowledge with students' lived realities [9], promote scientific literacy [10], and challenge cultural biases embedded in traditional instruction [11].

Numerous studies have demonstrated that integrating cultural responsiveness into science education contributes to improved student engagement [12], stronger identity development in STEM [13], and greater academic achievement [14], particularly among students from historically marginalized communities. Existing studies have approached CRT in science education from diverse angles, such as how teachers design culturally responsive curricula, interpret their professional roles, incorporate students' voices, and address controversial socio-scientific topics [15], [16], [17]. However, despite the growing interest, the landscape of research in this field remains fragmented [18], [19]. The literature spans multiple disciplines, methodologies, and cultural contexts, leading to a lack of cohesion in the development of a unified knowledge base.

At the same time, the global shift toward Education 4.0—a vision of education aligned with the Fourth Industrial Revolution—has emphasized the integration of technology, personalization, and lifelong learning in ways that are culturally and contextually meaningful [20], [21], [22]. Within this framework, CRT plays a vital role by ensuring that digital transformation in education does not ignore the sociocultural identities of learners [23]. In science education, the intersection of CRT and Education 4.0 can promote both technological literacy and cultural relevance, supporting the development of 21st-century competencies in diverse student populations [24], [25]. However, research that bridges these two domains—cultural responsiveness and future-ready science education—remains limited and fragmented.

Most existing studies tend to focus on specific settings—such as urban schools in North America or multicultural classrooms in Europe—making it difficult to generalize findings globally [26], [27]. In addition, while some reviews have explored CRT within broader educational frameworks, few have focused specifically on how it evolves within the context of science education across diverse geographic and institutional contexts. The conceptual diversity and varied terminology—such as "culturally relevant pedagogy," "culturally sustaining teaching," or "funds of knowledge"—further complicate efforts to synthesize the field systematically.

Given these challenges, there is a growing need to construct a comprehensive overview of how CRT has been conceptualized and applied within science learning. A mapping of publication trends, key contributors, and emerging thematic patterns can offer insights into the evolution of research in this domain. It can also highlight research gaps and underexplored areas that may be critical for future studies [28]. Such an overview can benefit not only researchers, but also educators, policymakers, and curriculum developers who seek to understand how CRT can be effectively integrated into science teaching practices across contexts—especially within the forward-looking agenda of Education 4.0.

This study addresses the gap by providing a structured and quantitative examination of the global research landscape on CRT in science education. Through a systematic mapping of publication data, this study identifies the most active regions, institutions, and scholars, reveals dominant and emerging themes, and uncovers collaboration patterns and potential research silos. While prior studies have reviewed CRT-related literature, this study adopts a more integrative and data-driven approach to analyze trends and thematic development over time.

The main contribution of this article is to provide a clearer understanding of how CRT has developed within science education research globally. In particular, it aims to support a more strategic and inclusive research agenda by illuminating knowledge structures, collaboration networks, and areas that require further scholarly attention. The findings are expected to serve as a valuable reference for academics, educational leaders, and policy stakeholders seeking to foster more culturally responsive and equitable science education systems—ones that are aligned with the values of Education 4.0. To guide the study, the following research questions are posed:

RQ1: How have publication trends related to culturally responsive teaching in science education evolved over the past two decades?

RQ2: Who are the major contributors (countries, institutions, authors) in this field, and what are their collaboration patterns?

RQ3: What are the dominant and emerging themes in CRT research within the context of science education?

RQ4: What gaps or underexplored areas can be identified from the thematic and structural mapping of the literature?

To address these questions, this article is organized as follows. Section 2 explains the research methodology, including data collection, screening criteria, and bibliometric analysis procedures. Section 3 presents the results and discussion, structured into four main parts: publication trends, key contributors and collaboration patterns, thematic landscape, and research gaps. Finally, Section 4 concludes the paper by summarizing key insights and offering actionable recommendations for future research, educational practice, and policy development related to culturally responsive teaching in science education.

2. Method

This study employed a bibliometric analysis to examine global research trends and emerging themes related to culturally responsive teaching (CRT) in science education. The analysis was conducted using Biblioshiny, a web-based interface of the bibliometrix package in R, which enables interactive and visual exploration of bibliometric data [29]. The method was designed to quantitatively map the structure, development, and conceptual landscape of scientific publications in this domain.

The dataset was retrieved from the Scopus database, which was selected due to its broader coverage of education and social science journals compared to other indexing platforms such as Web of Science, as well as its compatibility with Biblioshiny and related bibliometric tools. This selection ensures a comprehensive and methodologically consistent analysis, particularly for interdisciplinary topics like CRT in science education [30]. The search was conducted in June 2025 using a targeted query that captured variations in terminology related to both culturally responsive teaching and science education. The following Boolean query was applied to the title, abstract, and keyword fields: TITLE-ABS-KEY(("culturally responsive teaching" OR "culturally relevant pedagogy" OR "culturally sustaining pedagogy") AND ("science education" OR "science learning" OR "science teaching" OR "STEM education")).

The initial search results were exported in CSV formats. To ensure relevance and rigor, only peer-reviewed journal articles written in English were included. A manual screening of titles and abstracts was conducted to exclude documents that were not related to educational contexts or that only mentioned the keywords tangentially. Additionally, book chapters, reviews, editorials, and notes were excluded, along with duplicate entries and incomplete records.

The document selection process was documented and visualized using a PRISMA flow diagram (see Fig. 1), which outlines the stages of identification, screening, eligibility, and inclusion. This diagram provides transparency in the data curation process and ensures the replicability of the study's findings. After cleaning, the final dataset was analyzed using Biblioshiny. The bibliometric procedures included performance analysis (e.g., publication trends, most productive authors, countries, and journals), collaboration analysis (e.g., co-authorship and country collaboration networks), and conceptual structure analysis (e.g., keyword co-occurrence, thematic mapping, and topic evolution).

These analyses allowed the study to identify key contributors, trace thematic developments over time, and uncover gaps in the literature that may inform future research in CRT within science education.

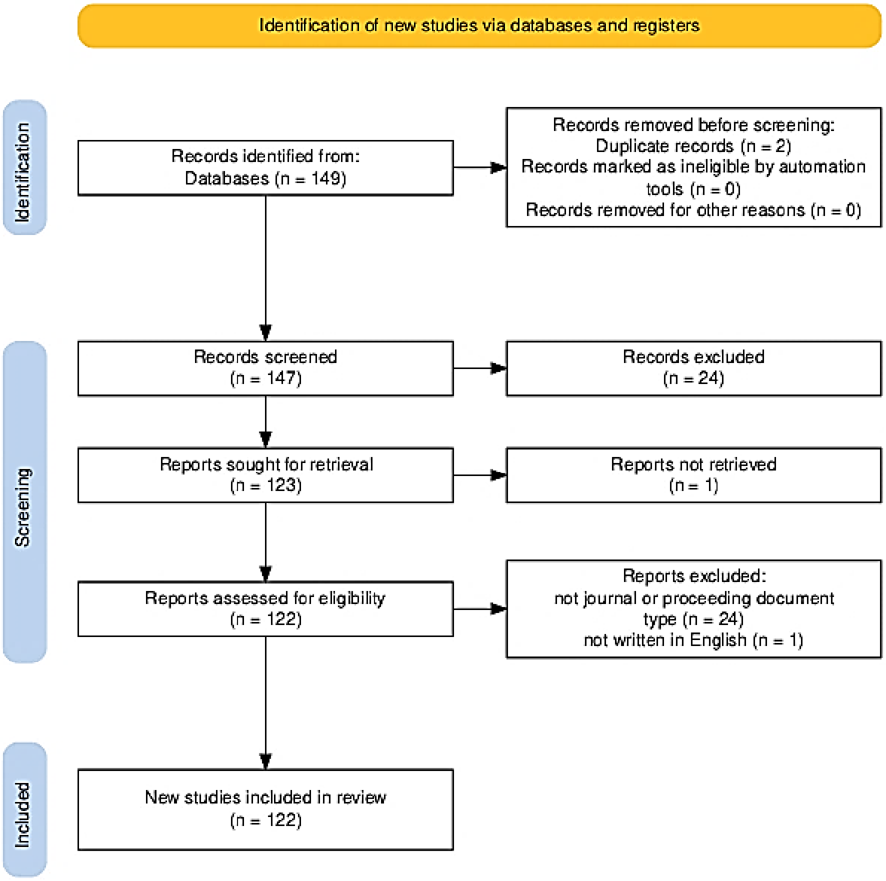

Fig. 1. PRISMA flow for record selection

Fig. 1 illustrates the PRISMA flow diagram outlining the study selection process in four phases: identification, screening, eligibility, and inclusion. In the identification phase, a total of 149 records were retrieved from the Scopus database. Before screening, 2 duplicate records were removed, resulting in 147 unique records for the next phase. During the screening phase, titles and abstracts of 147 records were reviewed, leading to the exclusion of 24 records that were irrelevant to the research scope. Additionally, 123 reports were sought for full-text retrieval; however, 1 report could not be retrieved due to access issues. In the eligibility phase, 122 reports underwent full-text assessment. Of these, 25 reports were excluded—24 due to document type not meeting the inclusion criteria (not journal or proceeding papers) and 1 report because it was not written in English. Finally, in the included phase, 122 studies were confirmed as eligible and included in the bibliometric analysis. These records formed the final dataset for examining global research trends on culturally responsive teaching in science education.

3. Results and Discussion

The bibliometric mapping conducted in this study provides a comprehensive overview of global research dynamics concerning culturally responsive teaching (CRT) in the context of science education. The results are systematically organized to address the four research questions outlined earlier. First, the analysis of publication trends and annual scientific output illustrates the temporal evolution and growing scholarly interest in this field. Second, the identification of key contributors—including countries, institutions, and authors—along with their collaboration networks, offers insights into the geographic distribution and structural patterns of academic cooperation. Third, thematic and keyword-based analyses are employed to uncover dominant and emerging topics, revealing how scholarly discourse has developed conceptually over time. Finally, through thematic mapping and co-word analyses, this study highlights potential research gaps and underexplored areas that may guide future investigations in CRT within science education. The findings not only reflect the current state of the literature but also support a more strategic and inclusive research agenda for equitable science learning globally.

3.1. Publication Trends of CRT in Science Education

This subsection highlights key patterns in publication growth, citation impact, and influential works within CRT-related science education research over time. The annual scientific production on culturally responsive teaching (CRT) in science education has shown a clear upward trajectory over the past two decades. As seen in Fig. 2, from 2008 to 2015, the number of publications remained relatively low and stable, with no more than three articles published annually. This indicates that scholarly interest in this field was still emerging during the early 2010s, possibly reflecting limited awareness or adoption of CRT frameworks in science education at the time.

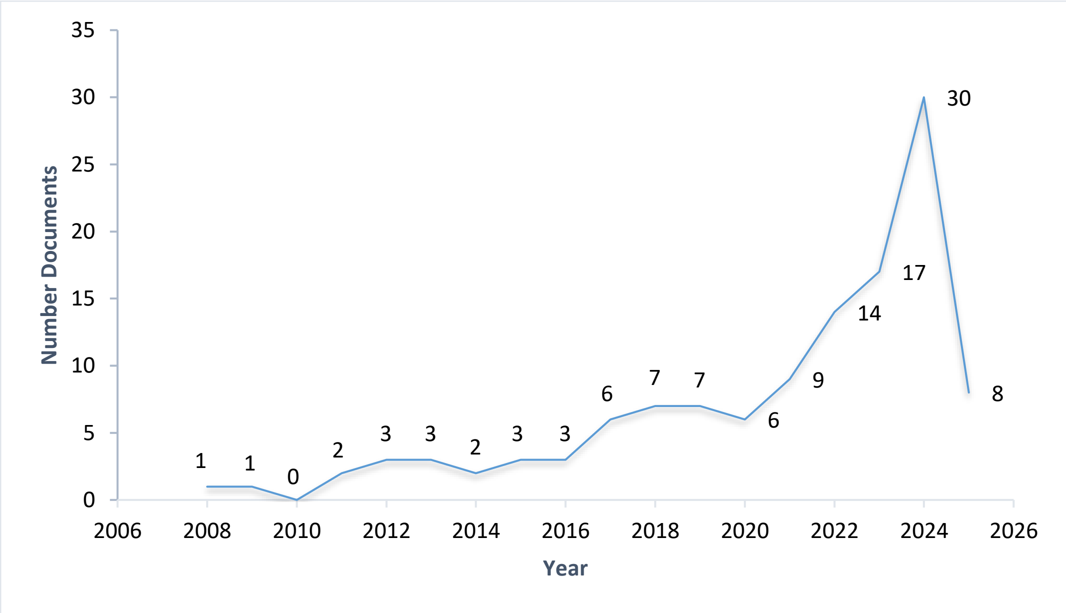

Fig. 2. Annual scientific production

Starting in 2017, a gradual increase is observed, with annual publications consistently exceeding five articles per year. Notably, there was a marked growth in output from 2021 onwards, culminating in a significant surge in 2024 with 30 publications—the highest number recorded to date. This sharp rise may reflect the growing global emphasis on educational equity, diversity, and inclusion in science classrooms, as well as the broader push toward transformative pedagogy in the context of Education 4.0 [31].

Although the data for 2025 is incomplete, with only eight publications recorded as of the analysis date, the upward trend suggests that research on CRT in science education is gaining momentum and evolving into a more established area of inquiry. This growth signals increasing scholarly recognition of the importance of culturally responsive approaches in promoting equity, engagement, and contextual relevance in science learning.

In addition to publication volume, an analysis of citation impact provides insights into the scholarly influence of studies on culturally responsive teaching (CRT) in science education over time. The data on average citations per article per year reveals several important trends. As shown in Table 1, articles published between 2011 and 2020 consistently received higher average annual citations compared to those published more recently. For instance, the year 2017 recorded the highest average citation rate at 5.09 citations per article per year, followed by 2020 with 4.3, and 2011 with 3.9. These figures suggest that works published during this period were particularly influential, possibly due to their role in shaping foundational discourse or addressing timely pedagogical concerns.

Table 1. Annual Citations per Year

Year	Mean Total Citations per Article	N	Mean Total Citations per Year	Citable Years
2008	42	1	2.33	18
2009	2	1	0.12	17
2011	58.5	2	3.9	15
2012	37.67	3	2.69	14
2013	19.33	3	1.49	13
2014	18	2	1.5	12
2015	12.33	3	1.12	11
2016	21.67	3	2.17	10
2017	45.83	6	5.09	9
2018	29.57	7	3.7	8
2019	25.14	7	3.59	7
2020	25.83	6	4.3	6
2021	6.56	9	1.31	5
2022	4.43	14	1.11	4
2023	3.59	17	1.2	3
2024	2.23	30	1.11	2
2025	0.5	8	0.5	1

In contrast, publications from more recent years (2021 onward) show lower citation averages, with 2024 and 2025 recording only 1.11 and 0.5 citations per article per year, respectively. This is likely a reflection of the shorter citable lifespan, as newer articles typically require more time to accumulate citations. Nevertheless, the steady rise in the number of publications in these years (e.g., 30 articles in 2024) indicates increasing research activity, even if the long-term impact is yet to be fully realized.

Interestingly, some early publications such as those from 2008 and 2011, although few in number, exhibit high citation impact, suggesting that pioneering studies in this field have served as important references for later research. These findings underscore that while publication volume is growing, citation analysis remains essential to identify works that have significantly shaped the intellectual landscape of CRT in science education.

In summary, the analysis indicates a clear upward trajectory in publication output, particularly peaking in 2024. This sharp rise likely reflects growing global attention to equity, diversity, and inclusion initiatives in education, especially following post-pandemic educational reforms and heightened awareness of social justice issues worldwide. Such trends underscore the expanding recognition of CRT as a critical component in shaping inclusive science education policies and practices.

In terms of scholarly impact, the most globally cited documents offer insight into the foundational and influential works that have shaped the discourse on culturally responsive teaching (CRT) in science education. The most cited article is Morales-Doyle (2017), published in Science Education, with a total of 230 citations. This study critically examined the role of CRT in politicizing science education, and its high citation count underscores its significance in advancing equity-focused pedagogical frameworks within the discipline.

Following this, Meyer (2011) published in Cultural Studies of Science Education has received 107 citations, highlighting the early contributions to the intersection of CRT and sociocultural theory in science teaching. Other highly influential works include Leonard (2018) in Journal of Teacher Education (91 citations) and Madkins (2019) in Science Education (81 citations), both of which emphasized culturally grounded STEM pedagogy and the importance of teacher identity in promoting equitable science learning.

Several of the most cited papers have been published in top-tier journals such as Science Education, Journal of Research in Science Teaching, and International Journal of Science Education, indicating that high-impact contributions in this field are well represented in reputable science education outlets. Interestingly, some authors, like Madkins, appear more than once in the top ten list, suggesting a strong and sustained contribution to this area of research. These high-impact studies are summarized in Table 2.

The diversity of publication venues—from education-focused journals to interdisciplinary and equity-centered conference proceedings—reflects the multidisciplinary nature of CRT research in science education. These frequently cited documents often serve as conceptual anchors for subsequent studies, demonstrating their role in shaping theoretical frameworks, methodological approaches, and policy-oriented discussions in the field.

Table 2. Most Global Cited Documents

Paper	DOI	Total Citations
Morales-Doyle D, 2017, Sci Educ	10.1002/sce.21305	230
Meyer X, 2011, Cult Stud Sci Educ	10.1007/s11422-011-9318-6	107
Leonard J, 2018, J Teach Educ	10.1177/0022487117732317	91
Madkins Tc, 2019, Sci Educ	10.1002/sce.21542	81
Laughter Jc, 2012, Urban Educ	10.1177/0042085912454443	67
Brown Jc, 2016, Int J Sci Educ	10.1080/09500693.2015.1136756	53
Grimberg Bi, 2013, J Res Sci Teach	10.1002/tea.21066	53
Johnson A, 2020, J Microbiol Biol Educ	10.1128/JMBE.V21I1.2097	50
Madkins Tc, 2019, Proc Res Equity Sustain Particip Eng, Comput, Technol, Respect	10.1109/RESPECT46404.2019.8985773	50
Upadhyay B, 2020, J Res Sci Teach	10.1002/tea.21626	47
Patchen T, 2008, Sci Educ	10.1002/sce.20282	42
Wallace T, 2012, Cult Stud Sci Educ	10.1007/s11422-012-9380-8	37
Underwood Jb, 2018, J Sci Teach Educ	10.1080/1046560X.2017.1423457	34

3.2. Key Contributors and Global Collaboration Patterns

This section presents key contributors, institutions, and collaboration networks that shape the global research landscape on CRT in science education. The bibliometric analysis of country-level contributions reveals that the United States dominates the research landscape on culturally responsive teaching (CRT) in science education (see Table 3). It ranks first both in terms of publication volume (1,575 articles) and total citations (1,227), indicating not only high productivity but also substantial influence in shaping the discourse globally. This strong presence likely reflects the longstanding emphasis on multicultural education and equity-driven pedagogies within the U.S. educational research community [32].

Other countries contributing significantly to the field in terms of article output include Australia (33 articles), Canada (31), Nigeria (24), and the United Kingdom (14). These countries represent diverse educational systems and sociocultural contexts, suggesting a growing international engagement with CRT frameworks in science education. Interestingly, Indonesia appears with a modest number of publications (4 articles), indicating early or emerging interest in this area within Southeast Asia.

When examining citation impact, the United Arab Emirates, Netherlands, New Zealand, and South Africa are also noteworthy, each appearing in the top ranks for total citations despite having fewer publications. For instance, the United Arab Emirates has accumulated 20 citations, and New Zealand and South Africa have 12 and 11 citations, respectively. This suggests that while these countries may produce fewer studies, some of their contributions are particularly impactful or frequently referenced by other scholars.

Table 3. Country Contribution in Publication and Citation

Country Rank	Country	N of Citations	Country	N of Articles
1	USA	1227	USA	1575
2	United Arab Emirates	20	Australia	33
3	Netherlands	14	Canada	31
4	New Zealand	12	Nigeria	24
5	South Africa	11	United Kingdom	14
6	Australia	10	Indonesia	4
7	Philippines	9		
8	Canada	8		

Overall, the data indicate that while CRT research in science education is still concentrated in a few high-income countries, there is a gradual diversification in terms of geographic participation. However, the relatively low representation from regions such as Asia, Latin America, and the Middle East (excluding UAE) points to potential gaps in global collaboration and knowledge exchange, which should be addressed to strengthen the international dialogue around culturally responsive science education.

In addition to country-level analysis, the identification of key contributors—at the author, institutional, and source (journal/proceedings) levels—offers a more granular view of the intellectual structure within CRT research in science education. As shown in Table 4, among the most prolific authors are Mensah F.M., Upadhyay B., Bailey D., Bowens C., and Brown J.C., all of whom have consistently published on topics related to culturally responsive pedagogy, equity in STEM education, and sociocultural frameworks in science classrooms. Their recurring presence suggests sustained commitment and leadership in advancing this area of inquiry.

Table 4. Most Relevant Contributors in Publication

Category	Contributors
Most relevant authors	Mensah FM; Upadhyay B; Bailey D; Bowens C; Brown JC; Gardner-Mccune C; Ketelhut DJ; Mak J; Riley AD; Xin Y.
Most relevant affiliations	University of Minnesota; University of Puerto Rico; University of California; University of Idaho; University of Hawai'I At Mānoa; Lagos State University; University of Michigan; Auburn University; Columbia University; Georgia Institute of Technology.
Most relevant sources	Cultural Studies of Science Education; Journal of Science Teacher Education; Asee Annual Conference and Exposition, Conference Proceedings; Education Sciences; Journal of Research in Science Teaching; ACM International Conference Proceeding Series; Frontiers in Education; Proceedings - 2023 Conference on Research in Equitable and Sustained Participation In Engineering, Computing, And Technology, Respect 2023; Respect 2024 - Proceedings of The Conference for Research on Equitable and Sustained Participation in Engineering, Computing, and Technology; Science Education.

From an institutional standpoint, the most active affiliations include major research universities in the United States and beyond, such as the University of Minnesota, University of Puerto Rico, University of California, and University of Michigan. Notably, institutions such as Lagos State University in Nigeria and the University of Hawai'i at Mānoa also appear among the top contributors, reflecting the field's expanding global footprint and the relevance of CRT frameworks in both Western and non-Western educational settings [33].

Regarding publication venues, the most relevant sources are highly specialized and well-regarded within the field of science education and educational equity. Leading journals such as Cultural Studies of Science Education, Journal of Science Teacher Education, Journal of Research in Science Teaching, and Science Education serve as primary platforms for disseminating CRT-related research. In addition, conference proceedings like those from ASEE and RESPECT (e.g., 2023 Conference on

Research in Equitable and Sustained Participation in Engineering, Computing, And Technology) highlight the intersection of CRT with engineering, computing, and broader STEM education domains, particularly in equity-focused settings.

This distribution of contributors underscores both the academic legitimacy and the interdisciplinary nature of CRT in science education, indicating that research in this field is shaped by a globally diverse yet thematically cohesive network of scholars, institutions, and publication outlets. The presence of equity-driven conference series and interdisciplinary journals further suggests a growing integration of CRT with movements like STEM inclusion, social justice education, and educational technology.

In addition to identifying major contributing countries, the international collaboration network offers valuable insight into the structure of cross-national scholarly partnerships in CRT-related science education research. As visualized in Fig. 3, the collaboration map reveals several distinct clusters of countries that engage in joint research efforts, with the United States (USA) clearly occupying the central position in the global network.

The USA demonstrates extensive collaborative links with a diverse set of countries including Canada, France, Japan, Philippines, Nepal, Brazil, and Kazakhstan, forming the largest and most interconnected cluster (highlighted in blue). This centrality underscores the USA's role not only as a dominant knowledge producer but also as a key facilitator of international scholarly exchange in the field. The breadth of its partnerships suggests strong institutional capacities for global research engagement and a willingness to support cross-contextual perspectives within CRT discourse.

Several smaller but distinct collaboration clusters are also evident. For instance, a strong regional partnership is seen between Australia, Qatar, and the United Arab Emirates (orange cluster), indicating growing interest in culturally responsive approaches within Middle Eastern and Oceanic educational contexts. Similarly, Netherlands and Greece, Norway and Germany, South Africa and Finland, as well as Nigeria and Burundi, each form bilateral collaborations that, while limited in size, may reflect shared linguistic or regional educational priorities.

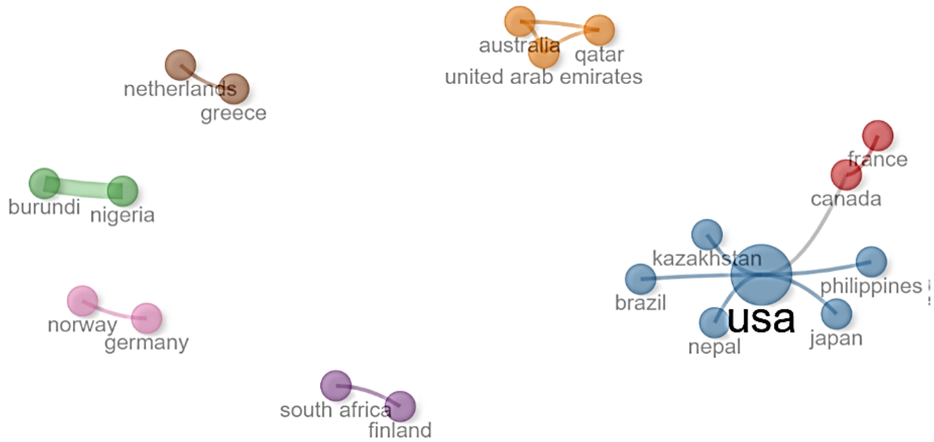

Fig. 3. International collaboration network

Notably, the map reveals that many countries are engaging in localized or dyadic collaborations, with fewer multilateral or intercontinental linkages beyond the dominant US-centered cluster. This suggests that despite the global relevance of CRT in science education, international collaboration remains uneven and, in many cases, regionally bounded. Countries such as Indonesia, India, and much of Latin America are notably absent from the central nodes of collaboration, highlighting potential opportunities for broader inclusion and knowledge exchange.

These findings indicate that the current landscape of international collaboration in CRT-related science education is characterized by asymmetrical networks, with a few central actors driving global engagement while many others remain peripherally connected. Strengthening transnational research partnerships—particularly those involving underrepresented regions—may help diversify the epistemological foundations of CRT and support the development of more context-sensitive frameworks that resonate across cultural and educational settings.

To further explore the interconnection between key contributors, their geographic origin, and thematic specialization, a Sankey diagram was generated (see Fig. 4). This visualization illustrates the flow of contributions from authors' countries (AU_CO), through individual authors (AU), to the dominant research themes or descriptors (DE). The left side of the diagram shows the United States (USA) as the most prolific contributor in terms of author affiliation, with the majority of influential scholars in this domain based in the U.S. Notably, other countries such as Kazakhstan, Nepal, Finland, and South Africa also appear, but with significantly fewer authors, suggesting limited contributions to this body of literature from regions outside North America.

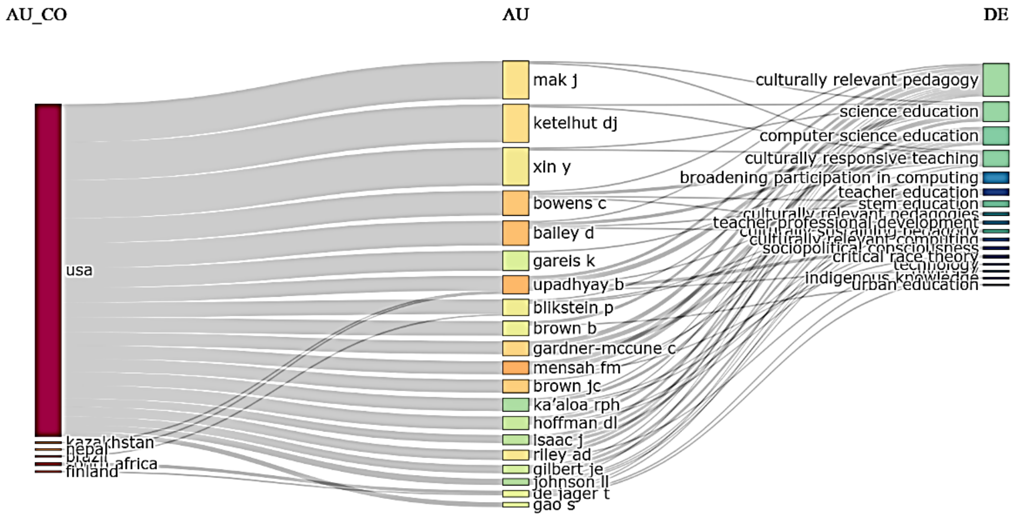

Fig. 4. Sankey diagram

In the center column, prominent scholars such as Mak J, Ketelhut DJ, Xin Y, Bowens C, Bailey D, Upadhyay B, Brown JC, Gardner-McCune C, and Mensah FM are shown as key nodes. These authors are connected to a broad range of research themes, indicating both high productivity and thematic diversity. For instance, Mak J and Ketelhut DJ are associated with culturally relevant pedagogy, computer science education, and broadening participation in computing, suggesting a focus on equitable access within digital and computational learning environments.

The rightmost column shows that the dominant themes associated with these authors include "culturally relevant pedagogy," "science education," "computer science education," "teacher education," and "culturally responsive teaching." Some authors are also connected to more specialized or emerging themes such as "critical race theory," "urban education," and "indigenous knowledge," reflecting the integration of sociopolitical frameworks and community-based knowledge systems into the CRT discourse.

The Sankey diagram thus provides a clear depiction of how scholarly production in CRT-related science education is geographically concentrated, thematically diverse, and driven by a relatively small group of recurring contributors, primarily located in the United States. This visualization also reinforces findings from earlier sections, showing that while the field is expanding in scope, it remains anchored by a core group of researchers whose work spans both theoretical and applied dimensions of CRT. These insights point to the opportunity—and necessity—for greater international diversification of authorship and thematic expansion. Future efforts might benefit from supporting scholars in underrepresented countries to contribute to this growing field, particularly with local cultural lenses that can enrich the global discourse on culturally responsive science education.

To summarize, the findings reveal a dominant concentration of research activity in the United States, supported by several international partners. However, collaboration patterns remain uneven, highlighting opportunities for strengthening global research exchanges—particularly involving underrepresented regions such as Southeast Asia and Latin America.

3.3. Thematic Landscape and Conceptual Structure

This subsection explores the conceptual structure of the field by identifying major research themes and their interconnections through co-word and thematic analyses. To gain a deeper understanding of the conceptual underpinnings and thematic structure of the field, a keyword co-occurrence network was generated based on author keywords and Keywords Plus. As illustrated in Fig. 5, this network reveals multiple clusters of interrelated terms that represent the main themes and conceptual intersections in the literature on culturally responsive teaching (CRT) within science education.

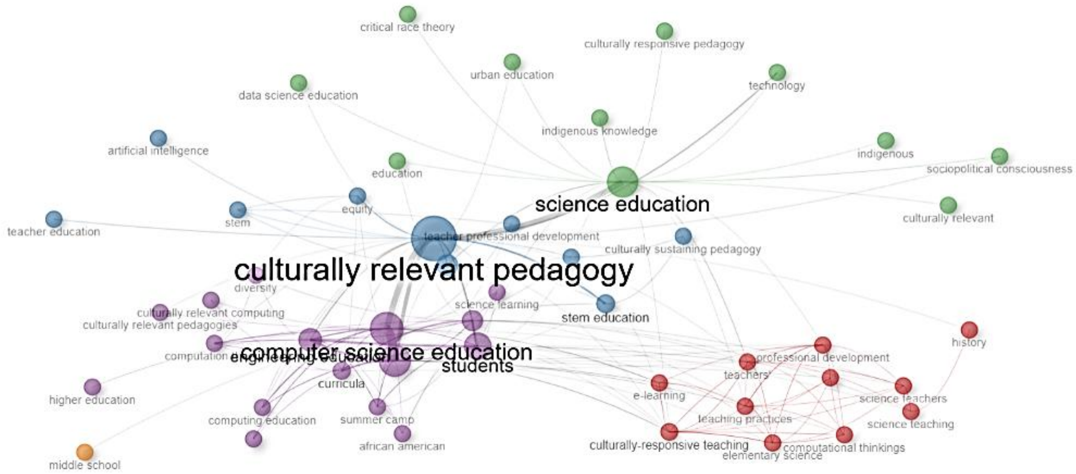

Fig. 5. Keyword co-occurrence network

The largest and most central node in the network is “culturally relevant pedagogy”, which serves as the dominant conceptual anchor, closely connected to other key terms such as “science education,” “STEM education,” “students,” and “computer science education”. This central position highlights the foundational role of CRT frameworks—especially Ladson-Billings’ culturally relevant pedagogy—in shaping research discourse across various STEM disciplines. The term “science education” itself appears in a prominent location, intersecting with both theoretical concepts and practical concerns such as teacher professional development, learning practices, and curriculum design.

Five thematic clusters emerge from the map keyword co-occurrence network. The green cluster includes concepts such as “culturally responsive pedagogy,” “indigenous knowledge,” “technology,” “urban education,” and “critical race theory.” This group represents a sociocultural and justice-oriented strand in CRT, which focuses on equity, marginalization, and the integration of indigenous and community-based knowledge systems into science learning. The blue cluster centers on science education and includes related terms like teacher education, STEM, artificial intelligence, and data science education. This cluster indicates growing interdisciplinary intersections between culturally responsive approaches and emerging technologies in education. The purple cluster is characterized by terms such as “computing education,” “summer camp,” “African American,” and “higher education,” highlighting CRT’s application in computer science and out-of-school learning environments, with a focus on underrepresented student populations. The red cluster focuses on practical pedagogy, including terms like “professional development,” “science teaching,” “e-learning,” “elementary science,” and “teaching practices.” This cluster reflects the implementation of CRT at the classroom level, especially in K–12 science instruction. Lastly, orange cluster represents education, science learning, diversity, and students.

The network also reveals important cross-cluster linkages. For example, "teacher professional development" connects both theoretical and practical strands, suggesting that the integration of CRT into science education is mediated through teacher training and capacity-building efforts. Similarly, the co-occurrence of terms such as "computational thinking" and "culturally responsive computing" indicates a novel area of intersection between equity-focused pedagogy and digital literacy.

Overall, the thematic landscape suggests a multidimensional and evolving field, where culturally responsive frameworks are applied not only in traditional science classrooms but also in interdisciplinary, digital, and community-based learning contexts. The prominence of terms like "indigenous knowledge" and "critical race theory" further underscores the growing influence of decolonial and anti-racist pedagogies within science education research.

These findings point to both the richness and complexity of the CRT research landscape. While foundational concepts remain central, emerging topics—especially those at the intersection of technology, equity, and teacher learning— suggest new directions for future inquiry, especially in underrepresented regional and disciplinary contexts. The presence of both well-established themes and newer, less explored concepts underscores the importance of continued thematic mapping to monitor the evolution and diversification of the field.

In addition to the co-occurrence network analysis, a keyword word cloud was generated to visualize the relative frequency of core concepts used in the literature on culturally responsive teaching (CRT) in science education. As presented in Fig. 6, the word cloud highlights the most frequently occurring terms, with font size representing the frequency of appearance across all documents analyzed.

Fig. 6. Keyword word cloud

The most prominent keywords include "computer science education," "science education," and "culturally responsive teaching," indicating the centrality of these themes in the research field. The prominence of computer science education suggests that culturally responsive approaches are gaining strong traction not only in traditional science classrooms but also in computing and STEM-related disciplines. This aligns with broader trends in education that emphasize equity and diversity in digital learning and technology fields.

Other highly frequent terms such as "STEM education," "students," "education computing," and "engineering education" reflect a multidisciplinary interest in integrating CRT frameworks across science, technology, engineering, and mathematics domains. These themes point to the increasing recognition that issues of culture, identity, and equity are relevant not only in social sciences but also in technical education spaces where historically marginalized groups remain underrepresented.

The appearance of terms like "social justice," "equity," "professional development," "indigenous knowledge," and "critical race theory" further indicates the growing integration of sociopolitical and decolonial perspectives within science education research. These keywords suggest that CRT is not merely a pedagogical approach, but also a transformative framework that intersects with broader struggles for justice and inclusion in education.

Other keywords such as "teacher professional development," "curricula," "urban education," and "teaching practices" reflect an applied focus, emphasizing the need for capacity-building and institutional change to support the implementation of CRT in diverse learning environments. Meanwhile, keywords like "middle school," "elementary science," and "summer camp" point to the range of educational levels and learning settings where CRT is being explored—from formal K–12 systems to informal science learning environments.

Overall, the word cloud visualization confirms the multidimensionality of CRT research in science education. It bridges theoretical foundations (e.g., critical race theory, indigenous knowledge), disciplinary application (e.g., STEM, engineering, computing), and pedagogical implementation (e.g., teaching practices, professional development). This breadth of focus reinforces the thematic diversity identified in the co-word network and underscores the growing maturity of CRT as a cross-cutting research agenda in contemporary science education discourse. In conclusion, while the thematic landscape demonstrates interdisciplinary richness, critical gaps persist, especially in integrating emerging topics like artificial intelligence and data science equity into CRT frameworks. These insights can guide future research priorities and curriculum development strategies in science education.

3.4. Research Gaps and Underexplored Areas

This subsection identifies critical gaps and less-explored areas within the CRT in science education research landscape, offering guidance for future scholarly efforts. To identify research gaps and assess the maturity of thematic developments in the field, a thematic map was generated (see Fig. 7). The map visualizes clusters of keywords based on their centrality (horizontal axis) and density (vertical axis), categorizing them into four quadrants: motor themes, niche themes, emerging or declining themes, and basic themes.

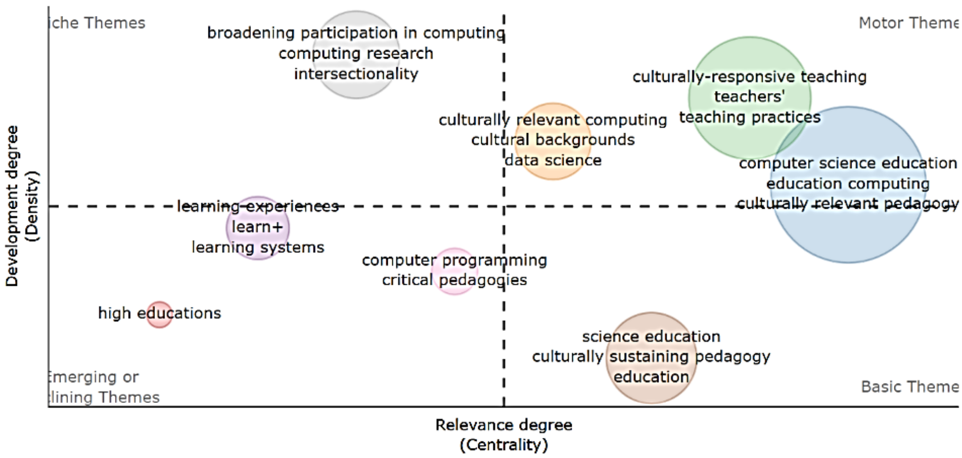

Fig. 7. Thematic map

Motor themes, located in the upper-right quadrant, are both highly developed and strongly connected to other themes. This quadrant includes "culturally responsive teaching," "teaching practices," "teachers," and "computer science education." These concepts form the intellectual core of the literature and represent well-established areas with strong scholarly attention and interconnectivity. Their presence suggests that a significant body of work has already explored pedagogical strategies and educator perspectives within the CRT and STEM context.

Basic themes, in the lower-right quadrant, are highly central but exhibit low density, indicating foundational but underdeveloped topics. Themes such as “science education,” “culturally sustaining pedagogy,” and “education” fall into this category. While these themes are broadly relevant, the low density implies that deeper, more nuanced explorations are still limited. This signals an opportunity for future research to build richer theoretical and empirical work around the application of CRT specifically within mainstream science curricula and culturally sustaining frameworks.

On the upper-left quadrant, niche themes such as “broadening participation in computing,” “intersectionality,” and “computing research” appear. These are highly developed internally but less connected to the broader field, suggesting that they represent specialized subfields. Though these topics have depth, they may not yet be widely integrated into the central discourse on CRT in science education. Nonetheless, their presence indicates potential areas for interdisciplinary expansion, particularly at the intersection of computing, equity, and inclusion.

The lower-left quadrant reveals emerging or declining themes—those with low centrality and low density. Terms such as “learning experiences,” “learning systems,” “higher education,” and “critical pedagogies” are situated here. These may represent newer lines of inquiry that have not yet gained traction or older topics whose relevance is waning. Particularly, the weak centrality of “critical pedagogies” is noteworthy, considering its foundational role in CRT theory. This suggests a need to revisit and revitalize critical pedagogy discourse within the applied context of science learning.

Another important observation lies in the position of “computer programming” and “data science,” which are located near the center but remain relatively low in density. These themes may hold promise as bridging areas between CRT and the rapidly expanding field of digital education but currently lack cohesive development. In sum, the thematic map reveals a field with several strong thematic cores but also many peripheral and underdeveloped areas. Future research should aim to: (1) deepen the theoretical engagement with basic themes like science education and culturally sustaining pedagogy; (2) bridge niche and core themes by integrating computing equity research with broader CRT discussions; and (3) strengthen the conceptual grounding of emerging themes like learning experiences and critical pedagogies through empirical validation and pedagogical design.

These gaps present promising opportunities for scholars to contribute to a more inclusive and cohesive knowledge landscape on culturally responsive science education. Moreover, these insights hold practical implications for both educators and policymakers, emphasizing the need to support interdisciplinary teacher training, foster equitable digital learning environments, and develop culturally sustaining science curricula that are responsive to local and global contexts. By addressing these underexplored areas, stakeholders can more effectively implement CRT frameworks that advance educational equity and inclusivity in diverse science learning settings.

3.5 Summary of Key Findings and Implications

This bibliometric analysis offers a comprehensive overview of global research trends, key contributors, thematic structures, and research gaps related to culturally responsive teaching (CRT) in science education. The findings underscore not only the field's conceptual maturity but also reveal critical gaps that warrant further attention.

From a policy perspective, these insights highlight the importance of promoting globally inclusive science education frameworks that integrate culturally sustaining pedagogy, particularly in regions with limited representation in CRT research. Policymakers should prioritize funding and support for cross-cultural collaboration initiatives and the development of inclusive science curricula.

For teacher training, the results emphasize the necessity of embedding CRT principles into professional development programs. This includes training science educators to integrate equity-centered pedagogies, indigenous knowledge systems, and technology-enhanced learning strategies. Teacher preparation institutions must consider both theoretical frameworks and practical classroom applications to ensure educators are equipped to navigate diverse learning environments.

In classroom practice, the identified thematic clusters suggest actionable directions: incorporating culturally responsive computing into science lessons, integrating critical race theory and indigenous knowledge into STEM education, and applying CRT approaches beyond traditional K–12 contexts into informal science learning settings such as summer camps and community programs.

Additionally, the unexpected concentration of CRT-related research in computer science education and digital equity—rather than in core science subjects like physics, biology, or chemistry—suggests a disciplinary imbalance. This finding opens an opportunity for expanding CRT integration into underrepresented science domains.

In sum, this study not only maps existing research landscapes but also provides clear implications for educational stakeholders. By addressing identified gaps and leveraging CRT frameworks, educational systems can advance toward more equitable, inclusive, and culturally relevant science learning environments globally.

4. Conclusion

This bibliometric study provides a systematic overview of global research trends on culturally responsive teaching (CRT) in science education. The findings demonstrate increasing scholarly recognition of CRT's importance in promoting equity, inclusivity, and cultural relevance, alongside key challenges such as geographic imbalance and limited integration of emerging technologies. While CRT has conceptually matured in areas like culturally relevant pedagogy and teacher development, underexplored topics such as critical pedagogies, culturally sustaining practices, and equity in data science highlight substantial opportunities for further investigation.

The results also reveal that CRT research remains concentrated in specific regions, particularly the United States, with notable gaps in representation from the Global South. Additionally, the thematic structure of the field reflects both interdisciplinary integration and isolated niche areas, indicating a need to build stronger connections across subfields. These insights underline the importance of expanding authorship diversity and fostering more inclusive international collaboration to enrich CRT scholarship globally.

In conclusion, while CRT in science education has achieved conceptual maturity in certain areas, there remains substantial room for growth in expanding global inclusivity, integrating interdisciplinary innovations, and deepening theoretical engagement. To translate these insights into practice, future research should prioritize: (1) empirical studies that explore CRT integration in diverse cultural and educational contexts, particularly outside the Global North; (2) development of teacher training models that embed CRT principles within STEM and computing education; and (3) policy initiatives that promote equitable science education through culturally sustaining curricula and inclusive digital learning environments. These recommendations are intended to guide scholars, educators, and policymakers in designing more equitable and culturally sustaining science learning environments for future generations.

Author Contribution: All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] H. Khalisah, R. Firmansyah, K. Munandar, and K. Kuntoyono, "Penerapan PjBL (Project Based Learning) dengan Pendekatan CRT (Culturally Responsive Teaching) untuk Meningkatkan Hasil Belajar Siswa Pada Materi Bioteknologi Kelas X-7 SMA Negeri 5 Jember," *J. Biol.*, vol. 1, no. 4, pp. 1–9, 2023,

https://doi.org/10.47134/biology.v1i4.1986.

[2] E. S. O'Leary *et al.*, "Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops," *Int. J. STEM Educ.*, vol. 7, no. 1, 2020, https://doi.org/10.1186/s40594-020-00230-7.

[3] Y. Rahmawati and A. Ridwan, "Empowering students' chemistry learning: The integration of ethnochemistry in culturally responsive teaching," *Chem. Bulg. J. Sci. Educ.*, vol. 26, no. 6, pp. 813–830, 2017, https://www.ceeol.com/search/article-detail?id=600081.

[4] Y. Rahmawati, H. R. Baeti, A. Ridwan, S. Suhartono, and R. Rafiuddin, "A culturally responsive teaching approach and ethnochemistry integration of Tegal culture for developing chemistry students' critical thinking skills in acid-based learning," *J. Phys. Conf. Ser.*, vol. 1402, no. 5, 2019, https://doi.org/10.1088/1742-6596/1402/5/055050.

[5] T. Smith, L. Avraamidou, and J. D. Adams, "Culturally relevant/responsive and sustaining pedagogies in science education: theoretical perspectives and curriculum implications," *Cult. Stud. Sci. Educ.*, vol. 17, no. 3, pp. 637–660, 2022, https://doi.org/10.1007/s11422-021-10082-4.

[6] M. Burchard, "Interactions and Gains in Cultural Responsiveness in Pre-Service Educators," *Pennsylvania Teach. Educ.*, vol. 21, no. 2, pp. 104–122, 2022, https://doi.org/10.46951/20222104.

[7] J. C. Brown and K. J. Crippen, "The Knowledge and Practices of High School Science Teachers in Pursuit of Cultural Responsiveness," *Sci. Educ.*, vol. 101, no. 1, pp. 99–133, 2017, https://doi.org/10.1002/sce.21250.

[8] D. Mhakure and F. S. Otulaja, "Culturally-Responsive Pedagogy in Science Education," *World Sci. Educ.*, pp. 81–100, 2017, https://doi.org/10.1007/978-94-6351-089-9_6.

[9] S. S. Coli, L. Matuszewich, X. D. Burgin, and M. C. Daniel, "Exploring University Teaching Assistants' Knowledge of the Power of Culturally Responsive Pedagogy," *Teach. Learn. Inq.*, vol. 12, pp. 1–18, 2024, https://doi.org/10.20343/teachlearninqu.12.27.

[10] R. Yerrick and M. Ridgeway, "Culturally responsive pedagogy, science literacy, and urban underrepresented science students," *Int. Perspect. Incl. Educ.*, vol. 11, no. 2, pp. 87–103, 2017, https://doi.org/10.1108/S1479-363620170000011007.

[11] C. A. Thomas, "District Certified Culturally Responsive Elementary Teachers and Their Mathematics Teaching Practices," *J. Urban Math. Educ.*, vol. 17, no. 1, pp. 10–47, 2024, https://doi.org/10.21423/jume-v17i1a480.

[12] A. C. Anyichie, D. L. Butler, and S. M. Nashon, "Exploring teacher practices for enhancing student engagement in culturally diverse classrooms," *J. Pedagog. Res.*, vol. 7, no. 5, pp. 183–207, 2023, https://doi.org/10.33902/JPR.202322739.

[13] J. A. Ogodo, "Culturally Responsive Pedagogical Knowledge: An Integrative Teacher Knowledge Base for Diversified STEM Classrooms," *Educ. Sci.*, vol. 14, no. 2, 2024, https://doi.org/10.3390/educsci14020124.

[14] G. Boutte and G. L. Johnson, "Culturally Relevant Teaching in Science Classrooms: Addressing Academic Achievement, Cultural Competence, and Critical Consciousness The Sociopolitical Context Culturally Relevant Pedagogy (CRP) Culturally Relevant Science Instruction CRP Example 1: Cell ," *Int. J. Multicult. Educ.*, vol. 12, no. 2, pp. 1–20, 2010, https://doi.org/10.18251/ijme.v12i2.343.

[15] I. M. Salma, N. Eurika, and F. Wulandari, "Upaya Peningkatan Literasi Sains Siswa Kelas XI MIPA 6 dengan PBL Berbasis Culturally Responsive Teaching Di SMAN Balung," *Educ. J. J. Educ. Res. Dev.*, vol. 7, no. 2, pp. 220–230, 2023, https://doi.org/10.31537/ej.v7i2.1267.

[16] F. Ware, "Warm demander pedagogy: Culturally responsive teaching that supports a culture of achievement for African American students," *Urban Educ.*, vol. 41, no. 4, pp. 427–456, 2006, https://doi.org/10.31537/ej.v7i2.1267.

[17] F. Idrus, "Initiating culturally responsive teaching for identity construction in the Malaysian classrooms," *English Lang. Teach.*, vol. 7, no. 4, pp. 53–63, 2014, https://doi.org/10.5539/elt.v7n4p53.

[18] Y. L. Wah and N. B. M. Nasri, "A Systematic Review: The Effect of Culturally Responsive Pedagogy on

Student Learning and Achievement," *Int. J. Acad. Res. Bus. Soc. Sci.*, vol. 9, no. 5, pp. 588–596, 2019, https://doi.org/10.6007/IJARBSS/v9-i5/5907.

[19] C. M. Hernandez, A. R. Morales, and M. G. Shroyer, "The development of a model of culturally responsive science and mathematics teaching," *Cult. Stud. Sci. Educ.*, vol. 8, no. 4, pp. 803–820, 2013, https://doi.org/10.1007/s11422-013-9544-1.

[20] B. R. Schirmer and A. S. Lockman, "Culturally Responsive Teaching in an Undergraduate Online General Education Course," *Online Learn. J.*, vol. 26, no. 3, pp. 132–148, 2022, https://doi.org/10.24059/olj.v26i3.2805.

[21] C. S. M. Ng, W. Chai, S. P. Chan, and K. K. H. Chung, "Hong Kong preschool teachers' utilization of culturally responsive teaching to teach Chinese to ethnic minority students: a qualitative exploration," *Asia Pacific J. Educ.*, vol. 42, no. 4, pp. 641–660, 2022, https://doi.org/10.1080/02188791.2021.1873102.

[22] K. C. P. Bostwick, A. J. Martin, K. Lowe, G. Vass, A. Woods, and T. L. Durksen, "A framework for teachers' culturally responsive teaching beliefs: Links to motivation to teach Aboriginal curriculum and relationships with Aboriginal students," *Teach. Teach. Educ.*, vol. 161, p. 105020, 2025, https://doi.org/10.1016/j.tate.2025.105020.

[23] J. Kehl, P. Krachum Ott, M. Schachner, and S. Civitillo, "Culturally responsive teaching in question: A multiple case study examining the complexity and interplay of teacher practices, beliefs, and microaggressions in Germany," *Teach. Teach. Educ.*, vol. 152, no. September, p. 104772, 2024, https://doi.org/10.1016/j.tate.2024.104772.

[24] P. Charoensilp, "Intercultural Sensitivity as a Factor in Perceived Culturally Responsive Teaching of Teachers in Northern Thailand," *rEFLections*, vol. 31, no. 1, pp. 90–117, 2024, https://doi.org/10.61508/refl.v31i1.271669.

[25] S. S. Ali, "Culturally Responsive Teaching : The Case of a Multicultural ELT Classroom in a Public Sector Asian University," *Korea TESOL J.*, vol. 17, no. 1, pp. 109–130, 2021, https://www.koreatesol.org/sites/default/files/pdf_publications/KTJ%2017-1%20web.pdf#page=119.

[26] A. I. Oladejo, P. A. Okebukola, T. T. Olateju, V. O. Akinola, A. Ebisin, and T. V. Dansu, "In Search of Culturally Responsive Tools for Meaningful Learning of Chemistry in Africa: We Stumbled on the Culturo-Techno-Contextual Approach," *J. Chem. Educ.*, vol. 99, no. 8, pp. 2919–2931, 2022, https://doi.org/10.1021/acs.jchemed.2c00126.

[27] N. M. Redmond, J. Shubert, P. C. Scales, J. Williams, and A. K. Syvertsen, "Unveiling potential: Culturally responsive teaching practices to catalyze social-emotional success in black youth," *Soc. Emot. Learn. Res. Pract. Policy*, vol. 5, no. April, p. 100124, 2025, https://doi.org/10.1016/j.sel.2025.100124.

[28] H. Go and M. Kang, "Metaverse tourism for sustainable tourism development: Tourism Agenda 2030," *Tour. Rev.*, vol. 78, no. 2, pp. 381–394, 2023, https://doi.org/10.1108/TR-02-2022-0102.

[29] A. Pabuçcu-Aklş, "Using innovative technology tools in organic chemistry education: bibliometric analysis," *Chem. Teach. Int.*, vol. 7, no. 1, pp. 141–156, 2024, https://doi.org/10.1515/cti-2024-0055.

[30] I. Irwanto, D. Wahyudiati, A. D. Saputro, and S. D. Laksana, "Research Trends and Applications of Gamification in Higher Education: A Bibliometric Analysis Spanning 2013–2022," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 5, pp. 19–41, 2023, https://doi.org/10.3991/ijet.v18i05.37021.

[31] S. Suparno, D. Purwana, A. Wibowo, and B. S. Narmaditya, "Industrial education 4.0: The role of human, technology, and data literacy," *J. Media Lit. Educ.*, vol. 15, no. 3, pp. 27–40, 2023, https://doi.org/10.23860/JMLE-2023-15-3-3.

[32] J. C. Brown and K. J. Crippen, "Designing for culturally responsive science education through professional development," *Int. J. Sci. Educ.*, vol. 38, no. 3, pp. 470–492, 2016, https://doi.org/10.1080/09500693.2015.1136756.

[33] J. B. Underwood and F. M. Mensah, "An Investigation of Science Teacher Educators' Perceptions of Culturally Relevant Pedagogy," *J. Sci. Teacher Educ.*, vol. 29, no. 1, pp. 46–64, 2018, https://doi.org/10.1080/1046560X.2017.1423457.