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MAPPING TWO DECADES OF RESEARCH ON SCIENCE EDUCATION IN SPECIAL EDUCATION: A BIBLIOMETRIC ANALYSIS

MAPEANDO DUAS DÉCADAS DE PESQUISA SOBRE EDUCAÇÃO CIENTÍFICA NA EDUCAÇÃO ESPECIAL: UMA ANÁLISE BIBLIOMÉTRICA

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Abstract
This study investigates the state of science education research within the field of special education by conducting a bibliometric analysis of articles indexed in the Web of Science database. Using the keyword "science education," twenty-eight studies published over the last two decades and focused on special education or disability were identified and examined. The analysis explored publication trends, country and institutional productivity, journal distribution, citation performance, link strength, and the most frequent keywords and abstract terms. Results indicate a marked increase in publication activity after 2020, highlighting a growing scholarly interest in this intersectional field. The United States emerged as the leading contributor, with the University of North Carolina identified as the most productive institution. Intellectual disability was the most frequently used keyword, while student appeared most often in abstracts, reflecting the field's emphasis on learner-centered approaches. Overall, the findings provide an overview of global research patterns in special education–related science education and offer a foundation for future studies seeking to map emerging themes and research gaps.

Keywords: Bibliometric Analysis. Intellectual Disability. Research Trends. Science Education. Special Education. Web of Science.

Resumo
Este estudo investiga o estado da pesquisa em educação científica no campo da educação especial, realizando uma análise bibliométrica de artigos indexados na base de dados Web of Science. Utilizando a palavra-chave "educação científica", foram identificados e examinados 28 estudos publicados nas últimas duas décadas e focados na educação especial ou na deficiência. A análise explorou tendências de publicação, produtividade por país e instituição, distribuição de periódicos, desempenho de citações, força de links e as palavras-chave e termos de resumos mais frequentes. Os resultados indicam um aumento acentuado na atividade de publicação após 2020, destacando um crescente interesse acadêmico neste campo interseccional. Os Estados Unidos emergiram como o principal contribuinte, com a Universidade da Carolina do Norte identificada como a instituição mais produtiva. Deficiência intelectual foi a palavra-chave mais utilizada, enquanto aluno apareceu com mais frequência nos resumos, refletindo a ênfase do campo em abordagens centradas no aluno. No geral, as descobertas fornecem uma visão geral dos padrões globais de pesquisa em educação científica relacionada à educação especial e oferecem uma base para estudos futuros que buscam mapear temas emergentes e lacunas de pesquisa.

Palavras-chave: *Análise Bibliométrica. Deficiência Intelectual. Tendências de Pesquisa. Educação Científica. Educação Especial. Web of Science.*

1 INTRODUCTION

Science education has increasingly been recognized as a core component of modern schooling, shifting from content-focused instruction toward approaches that emphasize inquiry, scientific literacy, and interdisciplinary learning (Bybee, 1997; Lederman, 2007; Osborne, 2005). This shift reflects broader efforts to equip all learners with the analytical and problem solving skills needed to navigate complex scientific and social issues (DeBoer, 2000; Kuhn, 1999). Parallel developments in special education have moved the field from segregation and care-based models toward inclusive frameworks that prioritize equitable participation (Ainscow, 2005; Florian, 2008; Paul et al., 2022; Winzer, 1993). As inclusive practices expand, ensuring meaningful access to science education for learners with special educational needs has become increasingly important, supported by research showing that science instruction enhances cognitive flexibility, conceptual understanding, problem solving, and communication skills (Jarret, 1999; Kıryak et al., 2022; Villanueva et al., 2012). Despite this progress, research uniting science education and special education remains scattered, making it difficult to track major developments and emerging trends. A bibliometric analysis can therefore provide a systematic overview of the field's intellectual structure and growth.

1.1 Foundations and development of science education

Science education aims to help learners understand scientific concepts, develop scientific process skills, and cultivate scientific reasoning that supports scientific literacy (Bybee, 1997; Lederman, 2007). It encompasses constructing scientific knowledge, fostering reasoning, and promoting literacy across domains (Harlen, 1999; Gizaw and Sota, 2023). Modern approaches move beyond content transmission (Magnusson et al., 1999; Crawford, 2014) to emphasize inquiry, the nature of science, and process skills within a holistic structure (Osborne, 2005; Ješková et al., 2022; Furtak et al., 2023). Contemporary science education spans traditional disciplines such as physics, chemistry, and biology, and extends to areas like STEAM and scientific attitudes (Yakman & Lee, 2012; Quigley, Herro et al., 2021).

Historically, science education gained prominence in the nineteenth century as industrialization increased the demand for structured scientific instruction (Roberts &

Bybee, 2014; Depaepe & Simon, 2020). Early implementations, particularly in Germany and England, remained content-focused and demonstration-based (Tampakis, 2011; Rocke, 2021). In the early twentieth century, structured instruction and science processes became more central in both the United States and Europe (Dewey, 1910; Rudolph, 2002). Dewey's experiential philosophy redirected the field toward laboratory-based, student-centered learning (Dewey, 1938; Hofstein et al., 2016). The 1957 Sputnik launch marked a major turning point, prompting large-scale investment and curricular reform (Bybee, 1997; DeBoer, 2014; Laugksch, 2000; Holbrook & Rannikmae, 2009). In the late twentieth century, scientific literacy emerged as a key goal, expanding science education's purpose beyond preparing scientists to supporting all individuals' everyday reasoning (Shamos, 1995; Bybee, 1997). In the twenty-first century, science education has become closely linked with STEM, inquiry-based methods, engineering design, and twenty-first-century competencies (Lederman, 2007; National Research Council, 2012). Digital technologies, robotics, coding, modeling, and artificial intelligence continue to transform science teaching into a multidisciplinary and practice-oriented field (Li et al., 2019; Almasri, 2024). Science education now supports evidence-based decision making and helps individuals engage with societal issues related to health, environment, and technology (DeBoer, 2000). Individuals with strong scientific reasoning skills more effectively interpret everyday situations and make informed judgments (Kuhn, 1999; Osborne, 2005; Carmona, 2025). These recognized benefits have led to widespread curriculum reforms aimed at ensuring that all learners access high-quality science education (Kaplan et al., 2024).

1.2 Science education for learners with special needs

Recent curriculum reforms highlight the need to provide science instruction not only for typically developing students but also for learners with special educational needs (Karaer & Melekoğlu, 2020). Historically, individuals with intellectual or physical disabilities were often isolated in care institutions where the focus was protection rather than education (Historic England, 2023). In the early twentieth century, specialized curricula emerged for children with intellectual disabilities, including Decroly's early programs (UNESCO [IBE], 1932). Diagnostic tools such as the Binet–Simon test also contributed to IQ-based classification systems (Binet, 1905; Anderson, 2017).

Throughout this period, increasing institutionalization and segregation limited access to general education.

Civil rights movements in the 1960s and 1970s shifted the field toward increased access and integration (Winzer, 1993; Dyson & Millward, 2000). Since the 2000s, inclusive education has emphasized participation, equal rights, and social inclusion within mainstream classrooms (Ainscow, 2005; Florian, 2008). Twenty-first-century perspectives place diversity, participation, and equitable access at the center of special education practices (Paul et al., 2022; Hornby, 2024; Tsou et al., 2024).

Science education holds particular value for learners with special needs. It promotes cognitive flexibility, causal reasoning, and everyday problem solving (Villanueva et al., 2012). Inquiry-based activities offer concrete, hands-on experiences that support mathematical thinking through observation, classification, experimentation, and inference (Jarret, 1999). From a language development standpoint, science lessons foster conceptual growth, academic vocabulary, and expressive communication (Kıryak et al., 2022). As a result, science instruction is widely seen as an essential domain that supports linguistic, cognitive, and social development in special education (Er Nas et al., 2023).

1.3 Significance of the study

Although research connecting science education and special education has increased, the field remains fragmented, and its global development is difficult to trace. A bibliometric analysis can reveal publication trends, key contributors, influential institutions, recurring themes, and conceptual patterns. Mapping these elements provides a clearer understanding of the field's evolution and highlights emerging gaps and opportunities for future research.

1.4 Purpose of the study and research questions

This study conducts a bibliometric analysis of research on science education in the field of special education indexed in the Web of Science database. By examining publication characteristics and thematic patterns, the study offers a structured overview to inform future scholarship. The research addresses the following questions:

(1)What is the annual distribution of publications on special education and science education?
(2)How do citation counts and link strengths of these articles vary by country?
(3)How do institutional link strengths compare across universities?
(4)What are the journal distributions in terms of publication count, citation count, and link strength?
(5)Which articles are most prominent based on citation count and link strength?
(6)Which topics appear most frequently in keywords?
(7)Which terms appear most frequently in abstracts?

2 METHOD

2.1 Research design

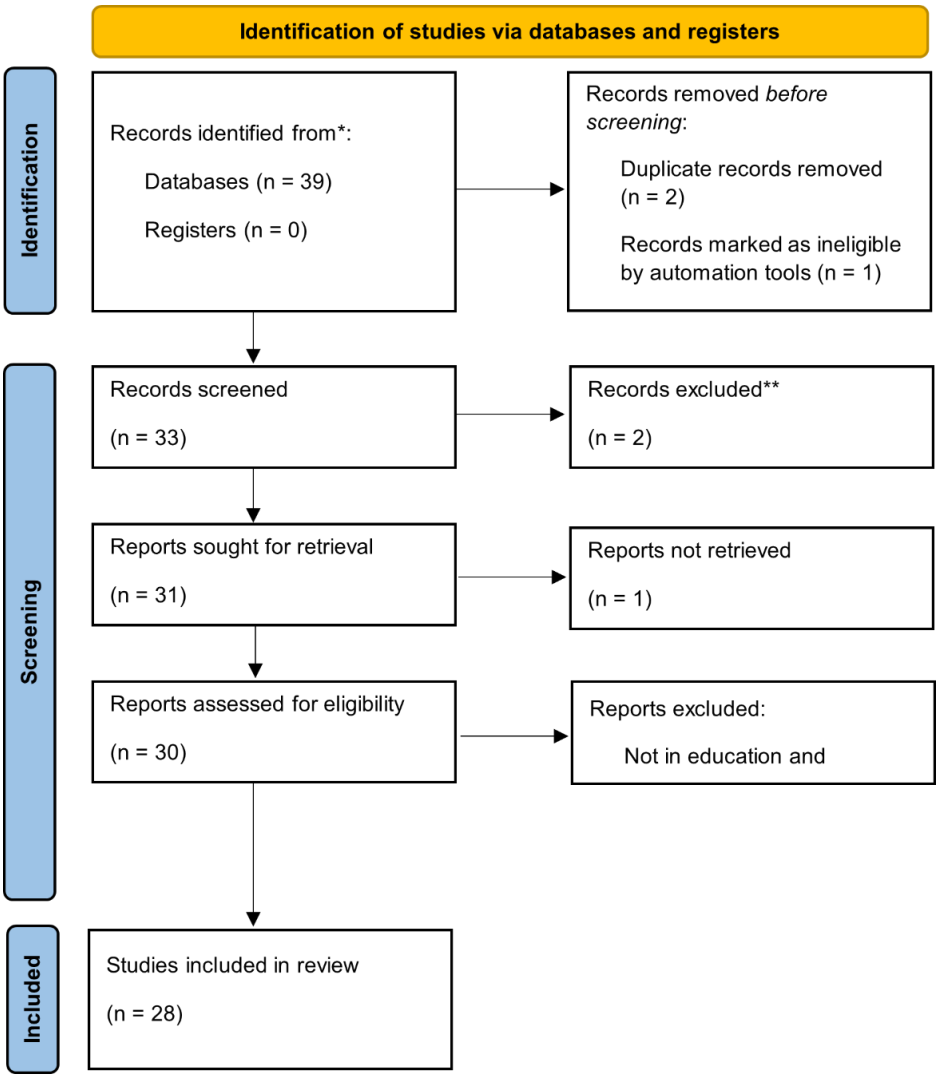
This study employed a bibliometric analysis to provide a comprehensive evaluation of academic publications on science education within the fields of special education and disability between 2005 and 2025. Bibliometric analysis systematically examines publication patterns, citation structures, and contributions of authors, countries, institutions, and journals through objective indicators (Aria & Cuccurullo, 2017; Donthu et al., 2021). This approach enables the identification of the position of science education in special education research, the conceptual strengths of the field, and existing research gaps.

2.2 Data collection

The dataset was retrieved from the Web of Science (WoS) Core Collection. The search was conducted using the Topic field with the terms “science education” combined with “special education” or “disability”. To ensure consistency, the search was limited to peer reviewed journal articles, resulting in an initial set of 33 publications. Applying an English-language filter reduced the dataset to 31 articles, and restricting the results to the education category yielded a final dataset of 28 articles. The article screening and selection process is summarized in Figure 1.

Figure 1

PRISMA flowchart



2.3 Data analysis

The analysis was carried out using WoS, a widely used and reputable index for high impact scientific publications (Falagas et al., 2008). VOSviewer software was employed to map and visualize bibliometric networks, including citation patterns, co-authorship links, and keyword co-occurrence. VOSviewer is particularly effective for identifying the intellectual and collaborative structure of research fields and for handling large datasets (Aria & Cuccurullo, 2017).

Using citation analysis, network visualizations, keyword co-occurrence, and text-mining techniques, the study identified thematic trends, emerging concepts, and the

developmental trajectory of research at the intersection of science education and special education (Donthu et al., 2021). Publications were analyzed by year, country, institution, and author, and citation distributions were examined to illustrate the field's evolution. Collectively, these analyses produced a comprehensive scientific map highlighting current knowledge and areas that require further investigation.

3 FINDINGS

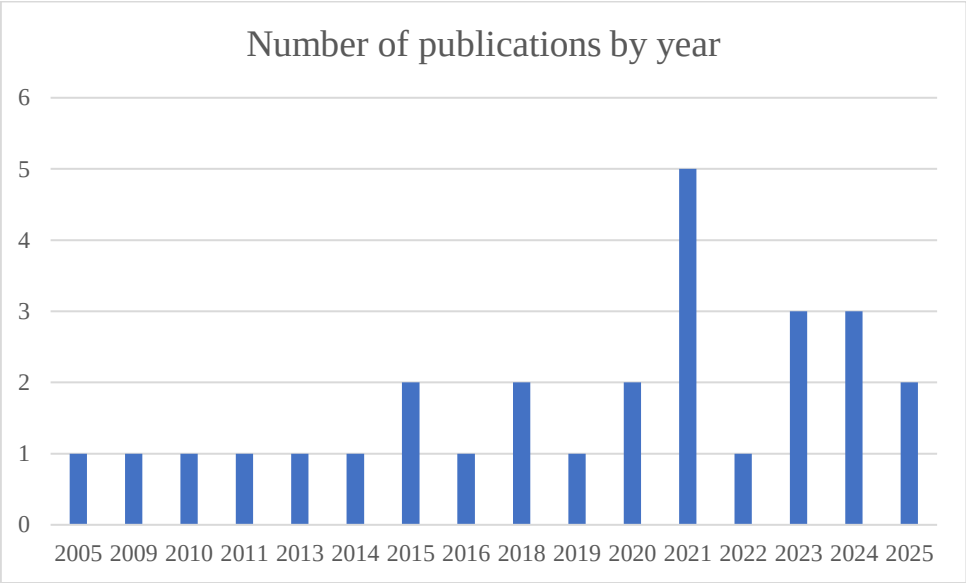
This section presents the bibliometric results of publications on science education within the context of special education and disability between 2005 and 2025. The analysis includes the annual distribution of publications, contributing countries and institutions, journals, keywords, and the most frequent terms appearing in abstracts. Together, these findings reveal the historical development of the field, its international distribution, key contributors, and areas that may represent future research opportunities.

3.1 Publication trends by year

Figure 2 shows that no relevant publications appeared in WoS prior to 2005, suggesting that the field began gaining visibility only after this date. Following 2005, the number of publications increased steadily, with a marked rise after 2015. This upward trend reflects growing scholarly interest in inclusive practices and the integration of special needs frameworks within science education. The acceleration observed in the early 2020s further indicates that the topic is receiving broader international attention. Because 2025 is not yet complete, the publication count for that year is expected to increase, demonstrating that academic production in this area remains ongoing.

Figure 2

Distribution by years



3.2 Country-level distribution

A threshold requiring at least two publications and at least one citation was applied to ensure meaningful comparison across countries. Although six countries initially appeared in the dataset, only three met these criteria, indicating that despite broad geographical representation, sustained and influential contributions originate from a smaller subset of nations. Table 1 shows that the United States is the clear leader with 18 publications and 401 citations, along with a total link strength (TLS) of 1, underscoring its central position in both research productivity and international collaboration. Canada, with 2 publications and 32 citations and a TLS of 1, demonstrates limited output but some integration into collaborative networks. Türkiye, with 7 publications but only 25 citations and no international link strength (TLS = 0), reflects notable productivity but lower visibility and limited involvement in global research networks. Overall, the data indicate that the United States dominates the field, Canada contributes modest yet collaborative work, and Türkiye appears productive but largely national in scope.

Table 1

Country-level distribution of the articles by citations and TLS

Country	Number of articles (n)	Citations	TLS
USA	18	401	1
Canada	2	32	1
Türkiye	7	25	0

3.3 Institutional contributions

Institutional analysis required each institution to have at least two publications and at least one citation, resulting in four institutions being included. As shown in Table 2, the University of North Carolina stands out with 3 publications and 174 citations, supported by a TLS of 1, which positions it as the most influential institution in the dataset. Vanderbilt University also produced 3 publications but amassed fewer citations (80), although its TLS of 1 indicates active involvement in collaborative research. Washington State University contributed 2 publications and 107 citations, demonstrating significant citation impact despite the absence of collaborative links (TLS = 0). Bolu Abant İzzet Baysal University produced 2 publications and 12 citations, yet its lack of link strength suggests limited international visibility. Taken together, the results show that U.S. institutions dominate scholarly output and influence, while the Turkish institution included contributes to publication volume but occupies a more peripheral role in international networks.

Table 2

Institutional distribution of the articles by citations and TLS

Institutions	Number of articles (n)	Citations	TLS
University of North Carolina	3	174	1
Vanderbilt University	3	80	1
Washington State University	2	107	0
Bolu Abant İzzet Baysal Üniversitesi.	2	12	0

3.4 Journal-level distribution

Journal analysis applied the same thresholds of at least two publications and at least one citation, resulting in four journals meeting the criteria. Table 3 and Figure 3 demonstrate that the Journal of Science Teacher Education published 2 articles, received

24 citations, and exhibited the highest TLS (16), indicating strong conceptual and collaborative centrality in the field. Research in Science Education also contributed 2 publications, receiving 12 citations and a TLS of 10, reflecting its prominent position within international science education research networks. School Science and Mathematics achieved 30 citations from 2 publications, showing considerable visibility, though its TLS of 6 suggests a somewhat less central role in collaborative structures. Focus on Autism and Other Developmental Disabilities recorded the highest citation count, with 58 citations from 2 publications, yet its low TLS (2) indicates limited integration into broader bibliometric networks despite its substantial impact. These findings show that journals contribute to the field in distinct ways: some through network centrality, others through citation strength, and others through consistent scholarly presence.

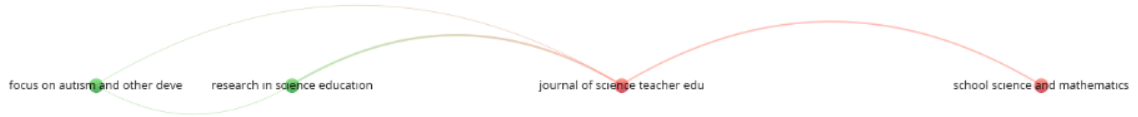
Table 3

Journal distribution of the articles by citations and TLS

Journal	Number of articles (n)	Citations	TLS
Journal of Science Teacher Education	2	24	16
Research in Science Education	2	12	10
Scholl Science and Mathematics	2	30	6
Focus on Autism and Other Developmental Disabilities	2	58	2

Figure 3

Bibliometric links of articles by journals



3.5 Citation performance and document-level link strength

Document-level bibliometric coupling was used to examine the citation performance and network structure of the publications. Using VOSviewer's "documents" mode, the minimum citation threshold was set to 1, and 38 of the initial 133 documents met this criterion. This allowed the network to focus on publications that had demonstrable scholarly visibility and to reveal the structural connections among cited

works. As shown in Table 4 and Figure 4, several publications stand out with respect to citation impact and total link strength (TLS). “Evaluating evidence-based practice in teaching science content to students with severe developmental disabilities” (Spooner et al., 2011) received the highest citation count (100), although its TLS value (47) indicates a relatively modest level of network connectivity. In contrast, “Using an early science curriculum to teach science vocabulary and concepts to students with severe developmental disabilities” (Smith et al., 2013) garnered fewer citations (29) but shows a substantially higher TLS value (67), reflecting strong integration into the wider research network. “Teaching science content and practices to students with intellectual disability and autism” (Knight et al., 2020) also holds a prominent position with 22 citations and a TLS of 56, illustrating both citation influence and strong bibliometric linkages. Although more recent, “Examining a science teacher’s instructional practices in the adoption of inclusive pedagogy” (Adu-Boateng & Goodnough, 2022) has gained visibility quickly, with 10 citations and a TLS of 51, demonstrating the field’s growing interest in inclusive pedagogical practices. Another notable publication, “Development of engineering habits of mind for students with intellectual disability” (Jimenez et al., 2021), shows moderate citation impact (11) alongside meaningful network engagement (TLS 42). Collectively, these results illustrate that some publications lead through citation impact while others contribute more significantly through network centrality, highlighting the field’s dual emphasis on scholarly influence and bibliometric connectivity.

Table 4

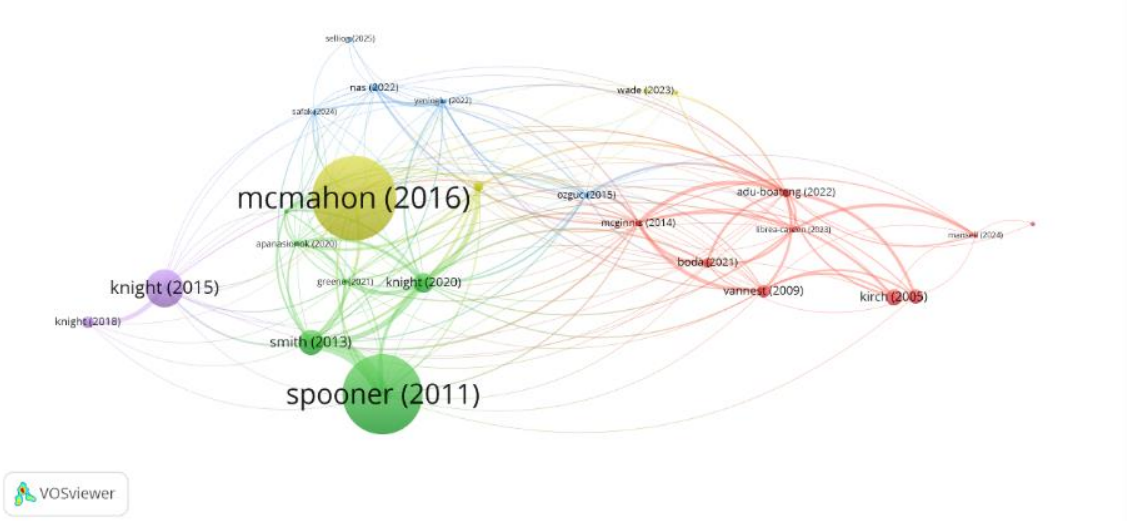
Articles by citation counts and TLS

Article Titles	Authors and Year	Citations	TLS
Using an early science curriculum to teach science vocabulary and concepts to students with severe developmental disabilities.	Smith, B. R., Spooner, F., Jimenez, B. A., & Browder, D. (2013).	29	67
Teaching science content and practices to students with intellectual disability and autism.	Knight, V. F., Wood, L., McKissick, B. R., & Kuntz, E. M. (2020).	22	56
Examining a science teacher’s instructional practices in the adoption of inclusive pedagogy: A qualitative case study.	Adu-Boateng, S., & Goodnough, K. (2022).	10	51
Evaluating evidence-based practice in teaching science content to students with severe developmental disabilities.	Spooner, F., Knight, V., Browder, D., Jimenez, B., & DiBiase, W. (2011).	100	47
Development of engineering habits of mind for students with intellectual disability.	Jimenez, B. A., Croft, G., Twine, J., & Gorey, J. (2021).	11	42

Note. Articles with top five TLS were included in the table.

Figure 4

Bibliometric links between articles



3.6 Frequently used keywords

The keyword analysis employed a minimum occurrence threshold of three to ensure conceptual coherence. Although 83 distinct keywords appeared across the dataset, only five met this criterion, indicating considerable terminological dispersion but also a small set of core concepts that structure the field. Table 5 and Figure 5 show that "intellectual disability" is the most frequently used keyword, appearing six times with a TLS value of 24, positioning it as a central anchor in the conceptual landscape. "Science education," with five occurrences and a TLS of 20, reflects the overarching disciplinary framework of the studies. "Science" appears four times and has a TLS of 18, highlighting direct attention to scientific content within instructional contexts. "Autism," despite appearing only three times, shows a high TLS of 15, suggesting strong connections to other frequently used concepts. "Special education," also appearing three times with a TLS of 11, serves as a broad organizing category. Overall, the findings indicate that research in this domain is conceptually concentrated around intellectual disability, science education, scientific content, autism, and special education, revealing both the thematic boundaries and focal points of the field.

Table 5

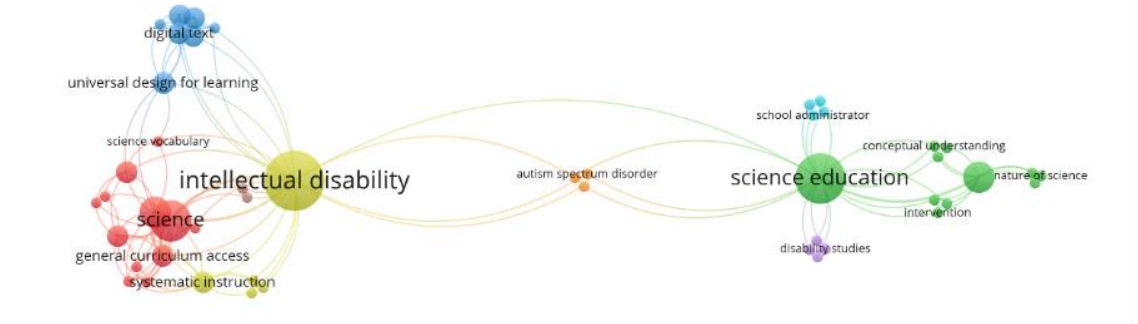
Keywords frequently occurring in the articles

Keywords	Occurrences	TLS
Intellectual disability	6	24
Science Education	5	20
Science	4	18
Autism	3	15
Special Education	3	11

Note. Articles with top five TLS were included in the table.

Figure 5

Bibliometric links of the keywords frequently occurring



3.7 Most frequent terms in abstract

A term co-occurrence analysis of article abstracts was conducted using VOSviewer, selecting the "all terms" option and applying binary counting. The threshold of at least 10 occurrences reduced the initial pool of 764 terms to five analytically meaningful items, excluding non-informative terms such as "article." As summarized in Table 6 and shown in Figure 7, "student" emerged as the most frequent term, appearing 97 times with a relevance score of 2.16, which underscores the predominantly learner-centered orientation of the research. "Study," with 49 occurrences and a relevance score of 0.75, highlights the methodological nature of the literature and the prevalence of empirical work. "Teacher" appears 30 times (relevance 1.27), reflecting sustained attention to instructional practices and educator roles. "Disability," occurring 32 times with a relevance value of 1.15, signals its role as a central conceptual category across the studies. Finally, "intellectual disability" appears 19 times with a relevance score of 0.84, demonstrating its importance as a specific research focus within the broader disability context. Taken together, these results show that the abstracts frequently foreground students, teachers, disability-related constructs, and empirical study designs, reflecting

the field's dual commitment to learner-centered inquiry and the examination of instructional practices.

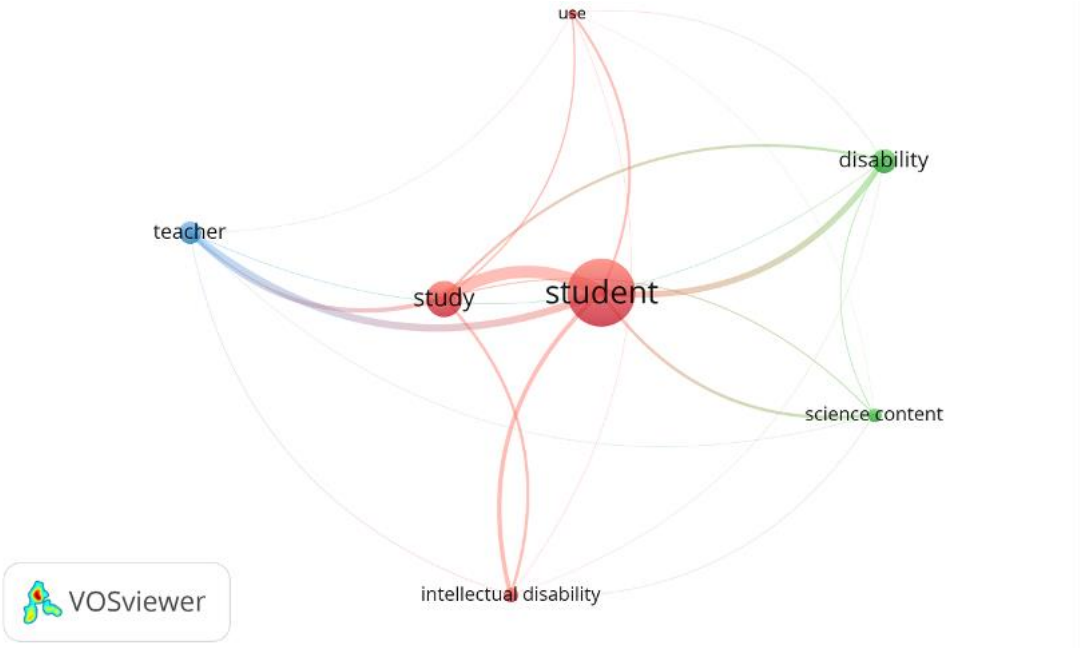
Table 6

Terms frequently occurring in the abstracts

Terms	Occurences	Relevance
Student	97	2.16
Teacher	30	1.27
Disability	32	1.15
Intellectual disability	19	0.84
Study	49	0.75

Figure 6

Frequently used terms in the abstracts



4 DISCUSSION

This bibliometric analysis provides an overview of how research at the intersection of science education and special education has developed over the past two decades. The steady increase in publications after 2005, with a noticeable acceleration after 2015 and particularly in the early 2020s, reflects growing international interest in inclusive science education and the participation of learners with special educational needs in science learning. These trends parallel wider movements in STEM education and inclusive education, where calls for equitable access to high-quality science learning have

become more visible (Kelley & Knowles, 2016; National Research Council, 2012). The recognition that science curricula should be designed to serve all learners, including those with disabilities, is now broadly accepted, and curriculum reforms increasingly reflect this principle (Rakap et al., 2023). The rising publication volume observed in this study can thus be interpreted as an academic response to broader social and policy-level commitments to equity and inclusion in science education.

At the same time, the findings reveal that research in this area is concentrated in a small number of countries. The United States clearly dominates both in terms of publication volume and citation impact, suggesting the presence of well-established research groups working specifically at the intersection of science education and special education. The prominence of institutions such as the University of North Carolina and Vanderbilt University, both of which combine high productivity with strong citation records, reinforces this interpretation. Scholars such as Spooner, Browder, and their colleagues have produced several highly cited works that function as intellectual anchors for the field (Spooner et al., 2011; Smith et al., 2013). Canada's smaller but internationally connected contribution shows that even relatively small research groups can exert influence through strategic participation in global networks. Türkiye appears as the third most productive country in terms of publication count, yet its lower citation rates and lack of link strength indicate that much of this work remains nationally oriented. Language barriers, limited access to international journals, and the under-publication of thesis research in indexed outlets may help explain this pattern (Rakap et al., 2023). These results highlight the importance of supporting researchers in underrepresented countries to move their work into internationally visible publication venues and to participate in cross-national collaborations.

The distribution of publications across journals underscores the interdisciplinary character of this research area. Rather than being concentrated in a single outlet, studies appear in science education journals such as Journal of Science Teacher Education, Research in Science Education, and School Science and Mathematics, as well as special education journals such as Focus on Autism and Other Developmental Disabilities. This pattern confirms that the topic sits at the boundary of two disciplinary communities. The fact that no journal hosts more than two publications suggests that there is not yet a clearly defined core outlet dedicated to science education for learners with special needs. Nevertheless, certain journals stand out from different angles. Journal of Science Teacher

Education exhibits high total link strength, indicating that it occupies a central position in the bibliometric network, while Focus on Autism and Other Developmental Disabilities hosts articles with the highest citation counts. School Science and Mathematics is notable for its overall visibility, and Research in Science Education provides a consistent, if smaller, stream of contributions. Together, these patterns suggest that research resonates in both science education and special education communities, but that the interaction between these communities may still be limited. Strengthening dialogue and collaboration across these fields could amplify the reach and impact of future work.

The analysis of citation performance and network connectivity at the document level points to a small set of key publications that shape the field. Spooner et al. (2011), which evaluates evidence-based practices for teaching science content to students with severe developmental disabilities, is the most highly cited article and can be considered a foundational reference. However, its relatively modest total link strength indicates that, while frequently cited, it is not as deeply embedded in the network of co-cited or bibliographically coupled works. Newer publications such as Knight et al. (2020), which addresses the teaching of science content and practices to students with intellectual disability and autism, combine higher citation counts with strong link strength, suggesting emerging centrality in the field. Similarly, Adu-Boateng and Goodnough's (2022) qualitative case study on inclusive pedagogy has achieved notable citation and network visibility in a short time, reflecting current interest in teachers' adoption of inclusive science teaching practices. Jimenez et al. (2021) extend the field by integrating an engineering-design perspective and focusing on the development of engineering habits of mind in students with intellectual disability. Collectively, these studies illustrate a shift from solely teaching science content toward integrating broader themes such as teacher practice, inclusive pedagogy, and STEM-oriented design.

The dominance of intellectual disability as a focal point, confirmed by both keyword and abstract analyses, indicates that learners with intellectual disabilities are at the center of current research efforts. The frequent co-occurrence of terms such as "intellectual disability," "science education," and "autism" suggests that the field has invested considerable attention in understanding how to support these groups in science learning. However, the relative absence of research on other disability categories, such as hearing or visual impairments and specific learning difficulties, points to a substantial gap. This is particularly striking given that science education is known to promote

cognitive flexibility, causal reasoning, and problem solving for a wide range of learners with special needs (Karabulut et al., 2021). Expanding research to address the experiences of learners with physical, sensory, and other types of disabilities would therefore be valuable both theoretically and practically.

Taken together, the findings show that the literature on science education in special education is still relatively small but steadily growing, geographically uneven, institutionally concentrated, and thematically focused on particular disability groups. Such patterns likely reflect broader inequalities in research funding, policy priorities, and institutional capacity (Hornby & Kauffman, 2024). At the same time, international advocacy around inclusive education and science literacy for all learners (Paul et al., 2022) suggests that demand for research in this area will continue to rise, including in developing and middle-income countries. Interdisciplinary collaboration between science education and special education researchers appears particularly crucial for advancing this agenda, as it can foster the development of more inclusive pedagogies, richer conceptual frameworks, and more contextually responsive interventions.

This study also has several limitations that should be taken into account when interpreting the findings. First, the analysis is limited to English-language articles indexed in the Web of Science database. As a result, relevant publications in other databases, non-indexed journals, national outlets, and conference proceedings are not captured. For example, Turkish-language articles in national journals or dissertations that have not been converted into journal publications fall outside the scope of this review. Consequently, the results reflect the behavior of internationally visible literature rather than the full body of work in the field. Second, the relatively small number of included articles constrains the breadth of network analyses. Thresholds applied to ensure interpretability led to the exclusion of single-publication countries and institutions, meaning that some actors remain invisible in the maps and tables. This may make the field appear more geographically concentrated than it truly is. Finally, bibliometric methods assess patterns of visibility and connectivity but do not directly evaluate the substantive quality or pedagogical impact of the publications (Donthu et al., 2021). Highly cited articles are not necessarily those with the most innovative or effective practices, and lower-cited works may nonetheless offer important conceptual or methodological contributions. The findings should therefore be read alongside qualitative reviews and expert judgment.

5 CONCLUSION AND IMPLICATIONS

This study conducted a bibliometric analysis of research on science education in the context of special education using articles indexed in the Web of Science database. The results show a clear upward trend in publication activity over the last twenty years, with a particularly sharp increase after 2020, indicating that inclusive science education has become a prominent concern for researchers. The analysis confirms the dominant role of the United States in shaping the field, both in terms of publication volume and citation impact, while countries such as Canada and Türkiye contribute to the literature but remain less influential at the international level. At the institutional level, universities such as the University of North Carolina and Vanderbilt University emerge as key hubs, producing highly cited work and shaping research agendas. The distribution of publications across both science education and special education journals underscores the genuinely interdisciplinary nature of the field. Keyword and abstract analyses further show that the literature is strongly centered on intellectual disability, students, and teachers, with a primary focus on how learners with special needs engage with science content and practices. Overall, the findings portray a small but expanding body of work, organized around a limited set of focal themes and concentrated within particular geographical and institutional contexts.

These patterns carry several implications for future research. First, there is a clear need to broaden the geographical base of scholarship. Researchers in underrepresented regions could benefit from participating in international consortia and collaborative networks to reduce the current geographical imbalance and enhance the global relevance of the field. Support for joint projects, co-authored publications, and cross-country comparative studies would help diversify perspectives and contextualize inclusive science education practices in different policy and resource environments. Second, thematic diversification is needed. While research on intellectual disability and autism has generated valuable insights, there is substantial scope for studies focusing on learners with sensory impairments, physical disabilities, learning difficulties, and multiple disabilities. Such work would deepen understanding of how science teaching can be adapted to diverse profiles and settings.

The findings also highlight important implications for teacher education and classroom practice. The frequent focus on students and teachers in the abstracts suggests

that teacher competencies, beliefs, and instructional strategies are central to the success of inclusive science education. Future research should therefore examine pre-service and in-service training programs that prepare teachers to design and implement accessible science instruction for learners with special needs, evaluate the effectiveness of these programs, and document exemplary classroom practices. This is especially important given that the benefits of science education for learners with disabilities, such as enhanced cognitive flexibility and problem solving (Karabulut et al., 2021), can only be realized if teachers are equipped to translate inclusive principles into concrete pedagogical actions.

Finally, the study has implications for policy and institutional decision making. By showing where scientific knowledge is concentrated and where gaps remain, the analysis provides evidence that can guide funding priorities, capacity-building initiatives, and curriculum reforms aimed at strengthening inclusive science education. Policymakers and educational leaders can use these insights to support research in neglected areas, encourage interdisciplinary collaboration between science educators and special educators, and ensure that policy frameworks explicitly recognize the right of learners with disabilities to participate meaningfully in science learning. In sum, the field of science education in special education is dynamic and holds considerable potential for growth. This study maps its current contours and points to the directions in which it can most productively expand.

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All authors contributed equally to the development of this article.

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All datasets relevant to this study's findings are fully available within the article.

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