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Global Research on Differentiated Instruction in High Schools and its Contribution to SDGs 4 Quality Education: A Bibliometric Analysis

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Abstract

This study examines the global development of differentiated instruction in secondary education through a comprehensive bibliometric analysis. The research aims to map publication trends, leading authors and institutions, intellectual structures, and thematic evolution to understand how differentiated instruction has progressed as a pedagogical approach for addressing learner diversity. Using data retrieved from a major scientific database, the study employed performance analysis and science-mapping techniques, including co-citation and co-occurrence analyses, to visualize research dynamics over a fifteen years period. The results show a substantial growth in publications since 2019 and reveal that research activity is concentrated in a limited number of countries, indicating persistent geographical imbalances in knowledge production. The intellectual structure highlights a clear separation between theoretical foundations and classroom implementation studies, while thematic evolution demonstrates a shift from conceptual discussions toward inclusive education, culturally responsive practices, formative assessment, and teacher professional learning. These findings indicate that differentiated instruction is increasingly recognized as a key element in promoting equitable and high-quality education, yet global research remains fragmented and unevenly distributed. The study concludes that future research should expand the geographical representation of studies, integrate cultural contexts more explicitly, and combine bibliometric evidence with empirical investigations to strengthen the theoretical practical coherence of differentiated instruction. This bibliometric mapping contributes to a deeper understanding of the field and informs future scholarly, policy, and pedagogical directions.

Keywords: Bibliometric analysis; Differentiated instruction; Inclusive education; High School education; Teacher development

1. Introduction

Major changes in the global education ecosystem over the past decade show that digitization and pedagogical transformation are two key elements in improving the quality of learning. This transformation is driven by technological developments that require educational institutions to adjust their learning strategies to be more adaptive and responsive to the needs of modern learners [1]. In various countries, educational reform now places technology and adaptive pedagogy as the main foundations for quality improvement, as seen in the global trend of

educational change triggered by digital innovation [2]. At the same time, education systems are gradually being required to facilitate social and economic progress from the local to the global level, affirming that quality education is a vital tool for sustainable development [3]. This pressure is even stronger when educational institutions are faced with demands for social responsibility and the need to address humanitarian issues and social inequality, including equal access to education [4]. This is in line with the increasing global attention to the issue of educational equity, especially for students from low socioeconomic backgrounds or those with diverse learning needs. Various studies show that academic stress, psychological pressure, and the inability to keep up with the pace of learning contribute to low student performance [5]. In addition, digital skills and student engagement levels in technology-based learning are still uneven, creating new challenges for teachers in creating an inclusive learning environment [6].

This gap becomes even more complex when socioeconomic factors are found to correlate with differences in students' mindsets and academic achievement, showing that academic ability does not stand alone but is influenced by the broader social context [7]. In addition, the emergence of new technologies such as artificial intelligence dialogue systems has raised concerns about the potential decline in cognitive abilities due to excessive dependence on digital tools [8]. In the teacher's experience, the disparity in perspective between teachers and students also affects the quality of the learning experience, including in the instructional process [9]. Based on these dynamics, differentiated learning has emerged as a pedagogical strategy that is considered capable of addressing the diversity of student characteristics in a more systematic manner. Global research has highlighted that differentiated learning has great potential in promoting educational equity and improving the quality of learning on an individual basis [10]. Conceptual and empirical reviews show that instructional differentiation helps teachers tailor learning content, processes, and products to the diverse needs of learners [11]. Research results Am [12], shows that differentiated learning has a positive impact on learning outcomes, especially in learning that involves diverse abilities.

A number of international studies show that teachers in various contexts still face challenges in planning and adapting learning to the diversity of students' readiness and needs. For example, exploration of differentiation practices in secondary schools in Europe confirms that teachers need systematic support to overcome barriers to implementing consistent differentiation strategies [13]. Teachers often find it difficult to design differentiated learning consistently due to limited professional competence, workload, and variations in pedagogical readiness. This perspective is reinforced by research by Ginja & Chen [14], shows that teachers need ongoing support in understanding and implementing differentiation in the classroom. In other contexts, teachers' beliefs, pedagogical mindset, and curriculum design skills are also important factors that influence the success of differentiation [15]. In China, research on multicultural attitudes and the implementation of differentiation reveals that teachers' professional readiness greatly influences the consistency of differentiation implementation in teacher education programs [16]. Meanwhile, a study in Hungary found that English teachers' beliefs about differentiation were strongly influenced by the national curriculum and teaching experience [17]. These global findings intersect with the Indonesian context, where the implementation of the Merdeka Belajar Curriculum further emphasizes the need to accommodate student diversity [18]. In Indonesia's Merdeka Belajar (Freedom of Learning) curriculum, teachers are required to tailor learning to the needs, interests, and readiness of their students, making differentiation skills essential [19]. Competency development through the TPACK approach has been proven to play a role in improving the readiness of Indonesian teachers in implementing differentiation [20]. In addition, the shift in education policy towards a more flexible model in the Merdeka Belajar (Freedom of Learning) program also shows the potential for improving the quality of secondary education through learning that is more responsive to student diversity [21].

The growing global and national attention to instructional differentiation has prompted various systematic reviews, including studies of teacher practices, learning strategies, and the integration of differentiation into the curriculum [22, 23, 24]. Although differentiated instruction is increasingly promoted as an effective approach to improving learning equity in secondary schools, global research on this topic still reveals several important gaps. Based on these research gaps, key questions arise regarding this study, including how global research on differentiated instruction at the secondary school level has developed and to what extent this research contributes

to the SDGS 4 Quality Education agenda. These questions cover aspects such as publication trends over time, the geographical distribution of research, patterns of mutually relevant publications, and the structure and evolution of themes that dominate scientific studies in this field. In addition, a deeper understanding is needed of how the direction and focus of this research reflect the principles of educational equity that are at the core of SDGS 4. This study aims to comprehensively map the global research developments on differentiated instruction in secondary schools through a bibliometric approach. Specifically, this study seeks to identify publication trends, the most productive countries and institutions, relevant collaborative document networks, as well as co-word patterns and the evolution of research themes over time. Thus, **Figure 1** provides an overview of the conceptual framework of this study regarding the position and direction of differentiated instruction research in supporting the global education agenda.

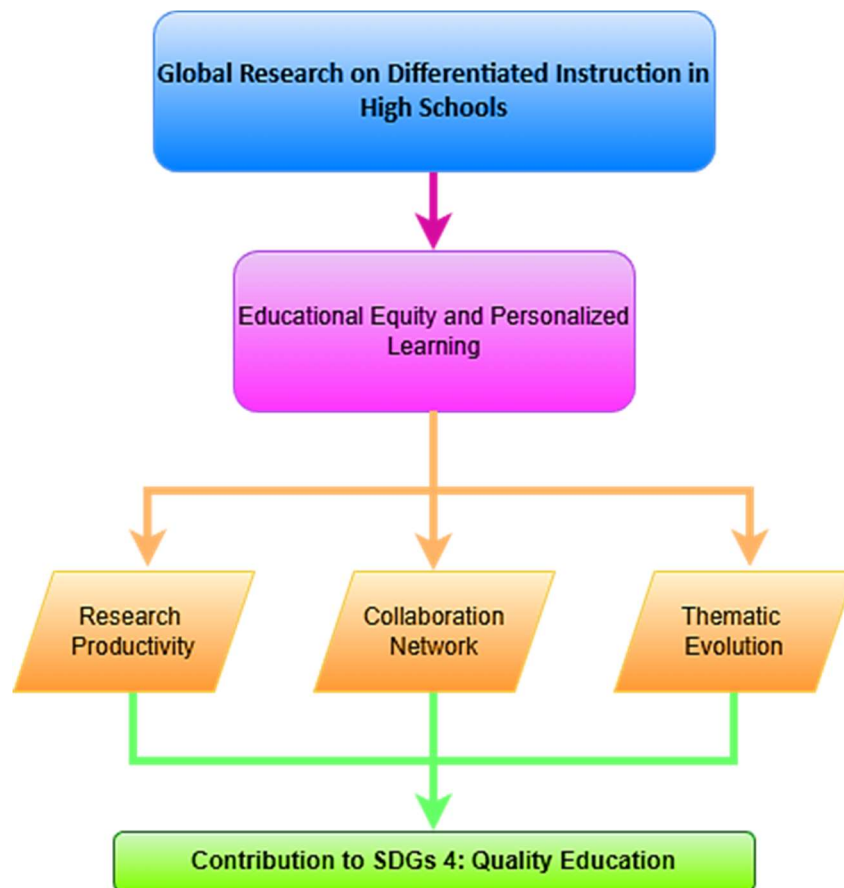


Fig 1. Conceptual Framework

2. Methods

2.1. Research Design

This study uses a bibliometric analysis design to map global developments in differentiated instruction at the secondary school level. This approach was chosen because it is capable of objectively assessing publication patterns, scientific influence, and the intellectual structure of a field through the analysis of international publication metadata [25]. Bibliometrics also provides a strong quantitative basis for identifying trends, collaborations, and the evolution of research themes, making it highly relevant for assessing the contribution of differentiated learning to SDGs 4 [26]. As an established methodology, bibliometrics enables researchers to assess the dynamics of science through measurable indicators such as citations, co-citations, and co-occurrences [27]. This framework is in line with

contemporary bibliometric guidelines that emphasize transparency of process, reproducibility of data, and systematic analysis of knowledge structures [28]. Thus, this research design provides a strong methodological basis for comprehensively explaining the global research landscape based on evidence.

2.2. Data Sources

This study uses Scopus as its sole data source due to its broad coverage, strong metadata standardization, and credibility in providing internationally reputable literature in educational studies. The use of a single, strictly indexed database provides consistency and reduces source selection bias, making it highly suitable for best practices in bibliometric research as recommended in studies on scientific search strategies [29]. The Boolean formulation is strictly designed to capture the entire range of terms related to differentiated instruction at the secondary school level, following the principles of accurate and representative query construction [30]. In addition, the search strategy was developed by considering common challenges in constructing search strategies, such as the selection of synonymous terms, contextual limitations, and clarity of scope, so that the findings would be comprehensive and methodologically accountable [31]. Search strategies using Boolean operators (AND, OR) along with structured search syntax that corresponds to academic terminology commonly used in international literature [32].

Table 1, shows the data sources and search strategy used to obtain the dataset using Boolean queries consisting of groups of terms related to the differentiation approach in learning and the context of secondary education. All publications that appeared from this formula were extracted in CSV format for further processing in the data cleaning and bibliometric analysis stages.

Table 1. Data Sources and Search Formulas

Data Sources	Search Formulas
Scopus	(("differentiated instruction" OR "differentiated teaching" OR "differentiated pedagogy" OR "differentiated classroom" OR "responsive teaching") AND ("high school" OR "secondary school" OR "upper secondary"))

2.3. Inclusion and Exclusion Criteria

Inclusion criteria were established to ensure that the publications analyzed truly represent the latest developments in differentiated learning at the secondary education level globally. The selection of the 2015–2025 times frame is intended to capture the dynamics of research over the past decade, reflecting changes in pedagogical paradigms, digital transformation, and the expansion of differentiation studies in the context of contemporary education. The selected documents are limited to journal articles because this type of publication is considered to have the most rigorous scientific review process, thus ensuring the quality and credibility of bibliometric data [28]. English is used as an additional constraint to maintain consistency in analysis and enable equivalent global comparisons between countries. Meanwhile, preference is given to open access articles to ensure transparency, traceability, and full accessibility to research content, in line with the spirit of open synthesis and scientific data openness as emphasized in the PRISMA 2020 guidelines [33]. All documents that do not meet these criteria, such as non-journal articles, publications in languages other than English, or documents published outside the specified time frame, are automatically excluded from the analysis because they have the potential to reduce the consistency of the dataset and confuse the interpretation of bibliometric trends. Thus, these criteria ensure that the entire dataset is of high quality, relevance, and comparability so that the analysis can produce an accurate and reliable picture of global trends.

Table 2. Inclusion and Exclusion Criteria

Category	Inclusion Criteria	Exclusion Criteria
Publication Year	2010–2025	< 2010
Document Type	Article	Review, conference paper, book chapter, editorial, note
Source Type	Journal	Non-journal sources
Language	English	Non-English

Category	Inclusion Criteria	Exclusion Criteria
Access	Open Access	Closed Access

2.4. Data Extraction and Processing

The data extraction and processing were carried out systematically to ensure transparency and reproducibility of the bibliometric analysis. All search results from Scopus were downloaded in comma-separated values format and processed through a selection stage following the PRISMA 2020 flow. This approach enables the structured identification and screening of documents, starting from the initial search stage, duplication removal, eligibility checks, to the determination of all articles that meet the analysis criteria. The use of the PRISMA 2020 framework is recommended because it offers international standards to improve the traceability of the study selection process and ensure methodological integrity in research synthesis [33].

After the selection stage, data was extracted based on key bibliographic elements including title, author, affiliation, keywords, abstract, year of publication, and journal source. All data was then processed using VOSviewer to map intellectual structures and patterns of interconnectivity between elements, such as co-authorship, co-citation, and co-occurrence. VOSviewer was chosen for its ability to intuitively visualize bibliometric structures through network, cluster, and density map representations, making it effective as a tool for both initial exploration and advanced analysis in understanding the research landscape [34]. The resulting visualization provides empirical insight into the dynamics of the global literature on differentiated instruction, including thematic developments and cross-country research concentrations [35]. As part of methodological transparency, the entire article extraction and selection process is shown in **Figure 2**, as a PRISMA 2020 Flow Diagram, which illustrates the number of documents at each stage of screening, from identification to final inclusion.

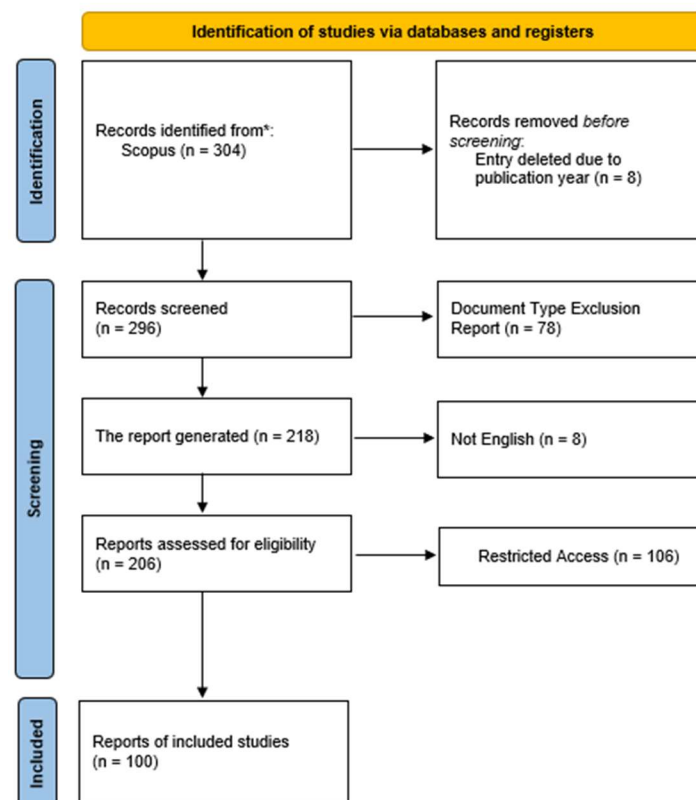


Fig 2. PRISMA 2020 Flowchart

Source: Haddaway et al. [36], with modification

2.5. Visualization Tools

The use of visualization tools is an important step in identifying patterns of scientific collaboration and the intellectual structure of a field of research. This study uses VOSviewer to produce three forms of visualization that are most relevant to the nature of the topic, namely co-authorship affiliation density visualization, co-occurrence author keywords overlay visualization, and co-citation network visualization. First, co-authorship analysis at the affiliation level is used to map global collaboration networks and trace how the distribution of research affiliations on differentiated instruction at the secondary school level are interconnected. Density-based visualization helps highlight centers of intensive publication activity so that dominant collaboration patterns can be observed comprehensively [37]. Second, this study also uses co-citation analysis to reveal the intellectual foundations that support differentiated instruction research at the secondary school level. This technique maps the connections between authors who are often cited together, indicating theoretical and methodological similarities between works [38]. Co-citation network visualization helps identify key literature groups, influential figures or publications, and conceptual foundations of a field of study. Thus, this analysis reinforces bibliometric interpretations by showing how theoretical structures in a field are constructed and evolve over time.

Third, co-occurrence analysis based on author keywords was applied to identify conceptual constructs, dominant themes, and emerging thematic trends. This approach is considered effective in topic mapping because of its ability to reveal semantic relationships between concepts, thereby enabling a clear mapping of the intellectual structure of the field of study [39]. Through overlay visualization, the evolution of key topics can be seen based on the year of emergence, providing a longitudinal understanding of the direction of research development [40]. The combination of these two visualization techniques provides a balanced picture of collaborative patterns and thematic landscapes, while ensuring that bibliometric interpretations are able to capture both geographical dynamics and conceptual developments in the global research corpus. The combination of these three visualization techniques provides a balanced picture of collaborative patterns, thematic landscapes, and theoretical foundations. This approach ensures that bibliometric analysis is able to capture geographical dynamics, conceptual developments, and intellectual structures in the global research corpus on differentiated instruction at the secondary school level.

2.6. Validation and Reliability Measure

Validity and reliability are important prerequisites in bibliometric analysis so that the findings are accurate, stable, and replicable. The first validation effort was carried out through the selection of a consistent and credible database, namely Scopus, given its broad international coverage, strict indexing standards, and high metadata accuracy. Scopus has been recognized as one of the most reliable sources in bibliometric studies because it provides a more diverse representation of scientific disciplines compared to several other databases [41]. Centralizing data sources in a single database also avoids duplication, metadata inconsistencies, and cross-database comparison biases that often arise in multi-database bibliometric studies.

The reliability stage was then reinforced through the application of a systematic and transparent analysis process. All research steps, from the formulation of the search strategy and document selection to data processing, followed standard bibliometric guidelines [28]. The use of clear inclusion-exclusion criteria, recording of the selection process using the PRISMA flow, and application of consistent analysis parameters in VOSviewer ensure that the research process can be replicated by other researchers. In addition, each step of data screening and processing is recorded in detail to maintain a methodological audit trail. With this approach, the validity and reliability of this study are maintained so that the findings obtained can be scientifically accounted for.

3. Results

3.1. Publication Dynamics

The development of publications on differentiated instruction at the high school level shows a progressive upward trend from 2010 to 2025. Figure 3, shows that in the early phase of 2010–2014, the number of publications

was still very low, fluctuating between zero and one document, reflecting that this topic was not yet a focus of global research. An upward trend began to emerge in 2015 when the number of publications rose to three documents, before declining again in 2016–2018. More significant changes emerged in 2019. Publications increased to five documents and continued to rise, entering a period of acceleration in 2020–2021, reaching six and fourteen documents, respectively. Despite a decline in 2022, the graph shows a strong recovery in 2023 and a sharp surge in 2024, reaching twenty-three documents. The year 2025 again recorded the highest number with twenty-four documents. This consistent upward pattern is reinforced by the polynomial trendline on the graph, which shows an upward curve with an increasingly steep gradient over time. This means that structurally, there has been an acceleration in global scientific interest in differentiated instruction at the high school level, especially in the last five years. This trend indicates that the field is not only growing but is also beginning to be seen as a strategic area that contributes to improving the quality of education in line with SDGs 4.

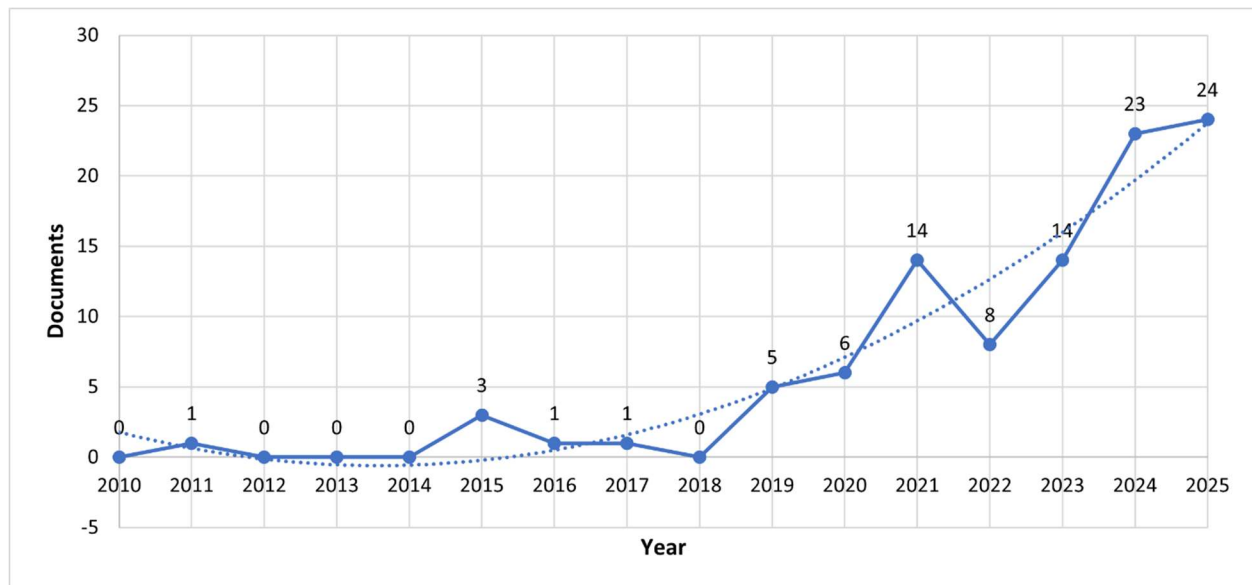


Fig 3. Publication Dynamics

3.2. Country Contributions

The distribution map in Figure 4, shows that research on differentiated instruction at the secondary school level has developed globally, although its intensity is uneven across countries. The distribution of publications shows strong clusters in Southeast Asia, Western Europe, and North America, while most countries in Africa and Central Asia have contributed only limited numbers. The data in Table 3 confirms Indonesia's dominance as the largest contributor with 19 documents. This position confirms the increasing national attention to the agenda of improving the quality of education and alignment with SDGs 4 targets. The United States follows with 12 publications, followed by Germany with 10 publications, indicating that this topic also occupies an important space in the research ecosystems of countries with established research capacities. Apart from these three major countries, significant contributions also came from South Africa with 9 publications, the Netherlands with 7 publications, and Australia, Malaysia, and Mexico, each producing 5 to 6 publications. This pattern indicates that the issue of differentiated learning is not only a concern for developed countries, but also for developing countries that are strengthening their inclusive education systems. In contrast, most other countries contributed minimally, with 1 to 2 publications. This includes countries in Africa, South Asia, Eastern Europe, and Latin America. This uneven pattern of contribution indicates that research on differentiated instruction is not yet evenly distributed globally, and there is still considerable room for other countries to strengthen their research agenda in this field. Overall, a total of 100

publications spread across more than 30 countries show that the study of differentiated instruction has become an international issue, but with research still concentrated in a few key countries.

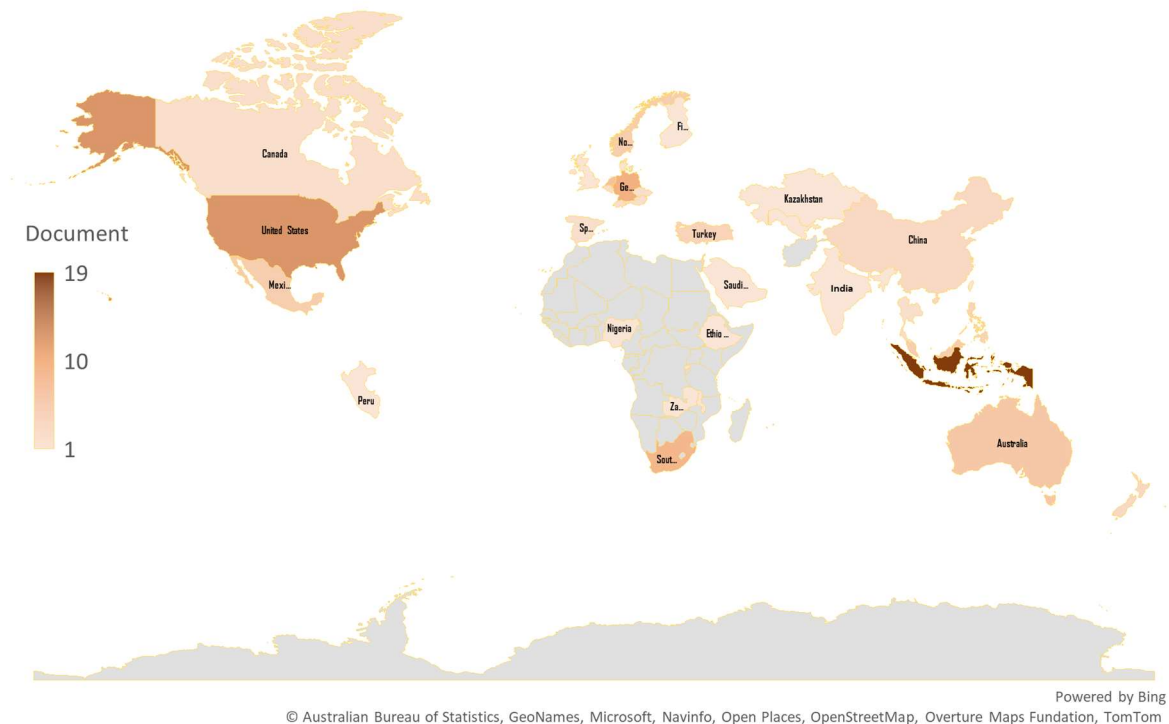


Fig 4. Country Distributions

Table 3. Publications by country

Country	Documents	Country	Documents
Indonesia	19	Switzerland	2
United States	12	Thailand	2
Germany	10	Denmark	1
South Africa	9	Ethiopia	1
Netherlands	7	Finland	1
Australia	6	Hong Kong	1
Malaysia	5	India	1
Mexico	5	Kazakhstan	1
Norway	5	Malawi	1
Philippines	4	Malta	1
Turkey	4	Nigeria	1
China	3	Peru	1
Israel	3	Rwanda	1
New Zealand	3	Saudi Arabia	1
Austria	2	Taiwan	1
Belgium	2	United Kingdom	1
Canada	2	Uzbekistan	1
Czech Republic	2	Zambiar	1
Spain	2	Total	100

3.3. The Intellectual Structure of Author Affiliation Analysis

Affiliation-based co-authorship analysis was used to map the intellectual structure of the research “Global Research on Differentiated Instruction in High Schools and its Contribution to SDG 4 Quality Education.” **Figure 5**, shows a visualization of the density of the co-authorship network based on author affiliation, while **Table 4**, summarizes the main affiliations along with indicators of productivity and collaboration strength.

Figure 5 shows that the collaboration network is not evenly distributed, but forms several zones with high density representing the most active affiliation clusters in publications on differentiated instruction at the high school level. The densest areas depict institutions that frequently appear in collaborative article writing, thus functioning as cores in the exchange of ideas and development of differentiated learning models that are in line with SDGs 4 on quality, inclusive, and equitable education. The pattern in **Figure 5** is reinforced by the quantitative information in **Table 4**, which contains the names of organizations, the number of documents, the number of citations, and the total link strength. Affiliations that have a combination of a high number of documents and citations with a large total link strength can be identified as key institutions, because they are not only productive in publishing works but also heavily involved in cross-institutional collaboration. This position places them as the main drivers of knowledge production on differentiated instruction and its implementation in secondary schools.

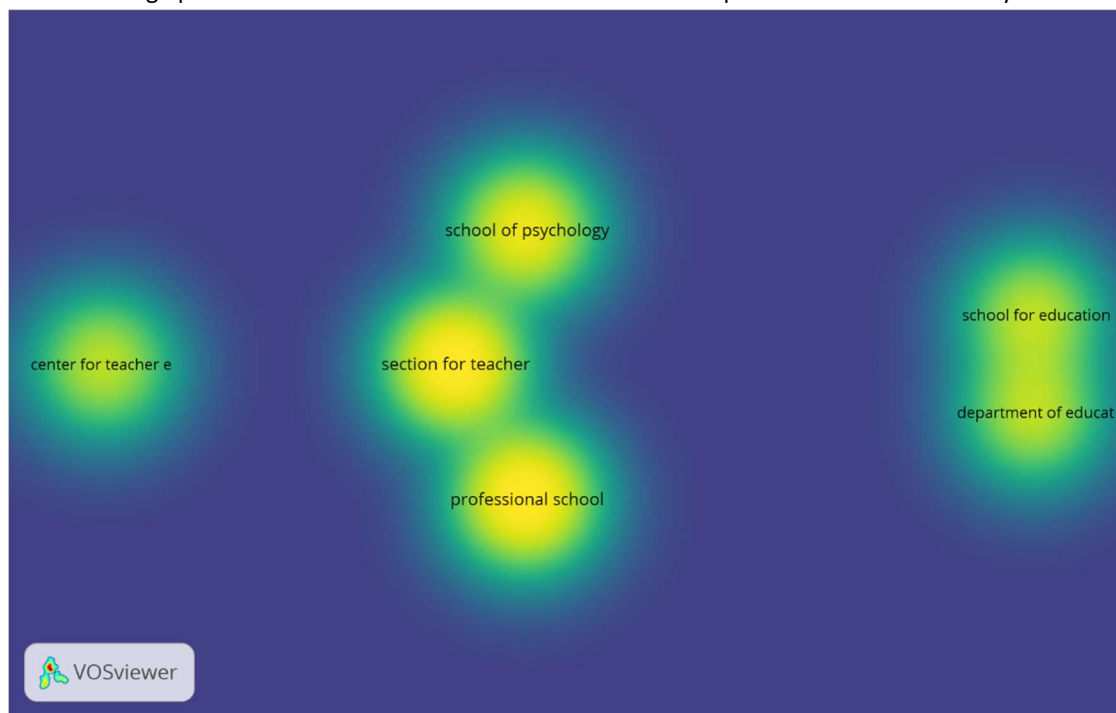


Fig 5. Visualization of co-authorship network density based on author affiliation

In contrast, **Table 4** also shows the existence of affiliations with lower numbers of documents and citations, as well as small or zero total link strength. In **Figure 5**, these types of affiliations tend to be located in less dense parts of the network, reflecting limited collaborative involvement. Nevertheless, their contribution remains important as an indicator of the widespread attention to differentiated instruction in various school and country contexts, while also indicating the existence of space for strengthening networks to accelerate the dissemination of learning practices that support the achievement of SDGs 4. The integration of **Figure 5** and **Table 4** shows that the intellectual structure of differentiated instruction research at the high school level is built through close relationships between institutions that form core clusters and connecting affiliations. The core cluster provides the main theoretical and practical foundation, while other affiliations play a role in expanding the scope of application to

various educational contexts. Thus, the author's analysis of affiliations confirms that institutional collaboration is an important prerequisite for the consolidation of knowledge and the strengthening of research contributions to SDG 4 Quality Education targets.

Table 4. Summary of the main author's affiliations and roles in the intellectual network structure

Organization	Documents	Citations	Total Link Strength
Professional School of Education, Humboldt-Universitat Zu Berlin, Germany	4	86	10
School of Psychology, Universidad De Monterrey, San Pedro Garza Garcia, Mexico	3	84	10
Section for Teacher Education and Research, Universitat Trier, Germany	4	89	10
Center for Teacher Education, Universitat Wien, Vienna, Austria	2	81	6
Department of Educational Sciences, Vrije Universiteit Brussels, Belgium	2	14	5
School for Educational Studies, Universiteit Hasselt, Belgium	2	14	2
College of Education, Psychology and Social Work, Adelaide, Australia	2	12	2
Department of Spanish and Literature, Tecnológico de Monterrey, Mexico	2	16	2
Education, University of Southern Queensland, Toowoomba, Australia	2	12	2
Vicerrectoria de Investigacion y transferencia de tecnologia, tecnologico de monterrey, Mexico	2	16	1
Universitas Ahmad Dahlan, Yogyakarta, Indonesia	2	22	1
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia	2	2	0
Department of Education, Masaryk University, Brno, Czech Republic	2	13	0
Griffith University, Brisbane, Australia	2	46	0
Interfacultair Centrum Voor Lerarenopleiding, Onderwijsontwikkeling en nascholing, Leiden, Netherlands	2	100	0
School of Education, University of the Witwatersrand, Johannesburg, South Africa	2	15	0
Universitas Negeri Makassar, Makassar, Indonesia	5	7	0
Universitat Trier, Trier, Germany	2	127	0

3.4. Intellectual Structure from Co-Citation Analysis

Co-citation analysis was used to map the intellectual structure of the research "Global Research on Differentiated Instruction in High Schools and its Contribution to SDGs 4 Quality Education." This analysis traced how often the authors' works were cited together in the same article, so that the authors who were the main conceptual references could be identified. In the initial stage, a minimum threshold of three citations was set for each author so that only works with sufficient influence were included in the mapping. Of the total 317 authors that appeared in the corpus, 10 authors met this criterion and were then further analyzed in the co-citation network. This screening ensures that the intellectual structure formed represents authors with significant contributions to the discourse on differentiated instruction at the high school level and its relationship to SDGs 4. This structure of interrelationships is visualized in **Figure 6**, which displays the co-citation network between authors.

Each node represents one author, while the connecting lines indicate the frequency of co-citations; the thicker the line and the closer the distance between nodes, the stronger the co-citation relationship between those

authors. **Figure 6**, shows the formation of two main clusters of interconnected authors: a cluster centered on Bowen and Glenn A., and a cluster centered on Brevik and Lisbeth M., with several other authors acting as connectors between the two clusters. The cluster centered on Bowen and Glenn A. can be seen as the main reference for the theoretical basis and methodological approach of differentiated instruction oriented towards improving the quality of learning processes and outcomes. Meanwhile, the Brevik–Lisbeth M. cluster represents studies that are more focused on specific application contexts, such as language learning support, literacy, or specific learning needs in middle school.

The co-citation relationship between the two clusters shows a conceptual bridge connecting the development of general differentiated instruction theory with practical practices that directly contribute to achieving SDG 4 targets on access to and quality of education. Overall, **Figure 6** confirms that the intellectual structure of differentiated instruction research in high schools is supported by a small group of key authors who are frequently cited together and form two main clusters of thought. The strong interconnections between authors within and between clusters indicate that knowledge development in this field occurs through intense conceptual dialogue, which in turn provides a scientific basis for more inclusive, adaptive, and equitable learning practices in line with the SDGs 4 Quality Education agenda.

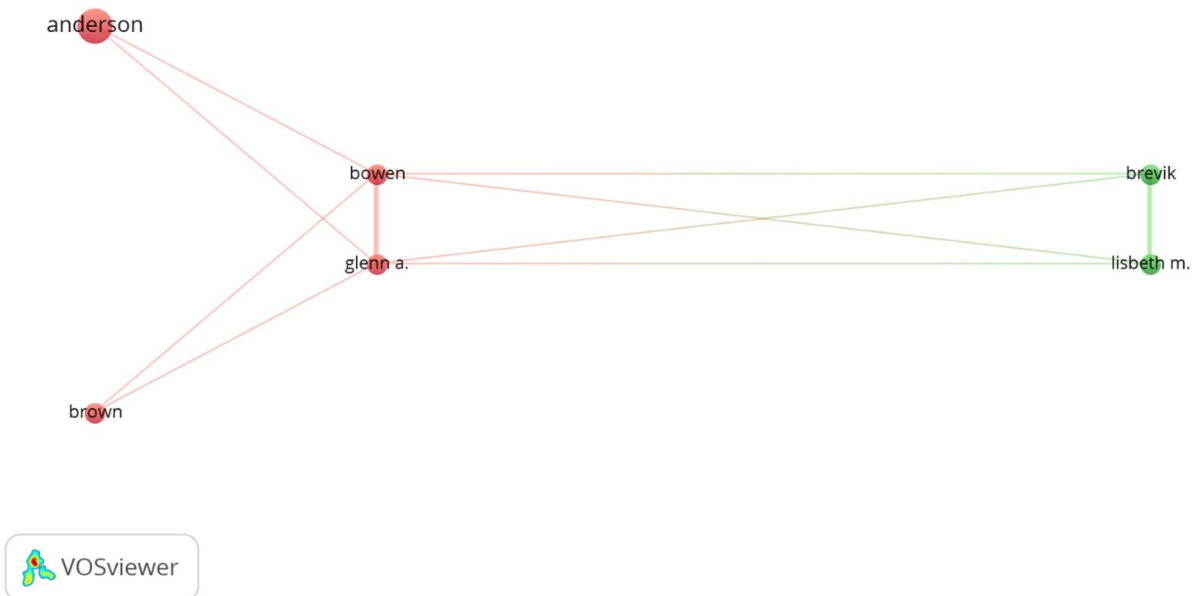


Fig 6. Intellectual Structure from Co-Citation Analysis

3.5. Thematic Evolution through Co-Occurrence Analysis

Keyword co-occurrence analysis was used to trace the evolution of research themes in the study “Global Research on Differentiated Instruction in High Schools and its Contribution to SDG 4 Quality Education.” In the initial stage, a minimum threshold of two occurrences was set for each keyword, so that out of a total of 384 keywords that appeared in the corpus, 32 keywords met the criteria and were included in the mapping. This threshold setting ensures that only themes that appear relatively consistently across various publications form the main thematic structure. Based on **Figure 7**, the co-occurrence overlay shows that the keyword “differentiated instruction” occupies a central position with the largest node size and the most connections to other keywords. This confirms that the entire theme network centers on the study of differentiated learning, while other keywords are grouped as sub-themes that explain the context, objectives, and implementation approaches at the secondary/high school level.

The color of the nodes shifts from blue to yellow, illustrating chronological development, where earlier themes tend to be bluish in color, while relatively new themes are greenish to yellowish in color.

Keywords surrounding the core term “differentiated instruction” include groups of keywords that describe a focus on educational context and objectives, such as “secondary education,” “high school,” “inclusive education,” “culturally responsive teaching,” “diversity,” and “inclusion.” The strong connection between these keywords shows that differentiated research in secondary schools is closely related to efforts to build inclusive learning that is responsive to student diversity. This is in line with SDGs 4, which emphasizes equal access, non-discrimination, and quality learning experiences for all. Another prominent theme is a cluster of keywords related to professional support and teacher capacity building, such as “pre-service teacher education,” “professional learning,” and “educational innovation.” The co-occurrence pattern between these keywords and “differentiated instruction” and “inclusive education” shows that differentiated learning innovation in high schools is understood not only as a strategy at the classroom level but also as an agenda for teacher competency development through pre-service teacher education and continuing professional development programs.

In addition, there are several more specific sub-themes such as “language learning,” “refugees,” “formative assessment,” and “algebra” that are connected to the core of differentiated instruction. The presence of these keywords indicates that the research not only discusses the general principles of differentiation, but also its application in specific contexts: for example, language learning for students from diverse backgrounds, learning support for refugee students, the application of formative assessment to monitor individual progress, or the application of differentiation to specific mathematics topics such as algebra. These sub-themes indicate a deepening of research towards more contextual and measurable practices. Overall, the co-occurrence map reveals that the thematic evolution of differentiated instruction research in secondary schools has moved from a focus on basic concepts and the context of secondary education towards the integration of issues of inclusivity, diversity, and culturally responsive learning, accompanied by an increasingly strong emphasis on teacher development and formative assessment. This pattern of thematic interrelationships illustrates how the research community is gradually aligning differentiated instruction practices with SDGs 4, namely providing inclusive and equitable quality education for all high school students.

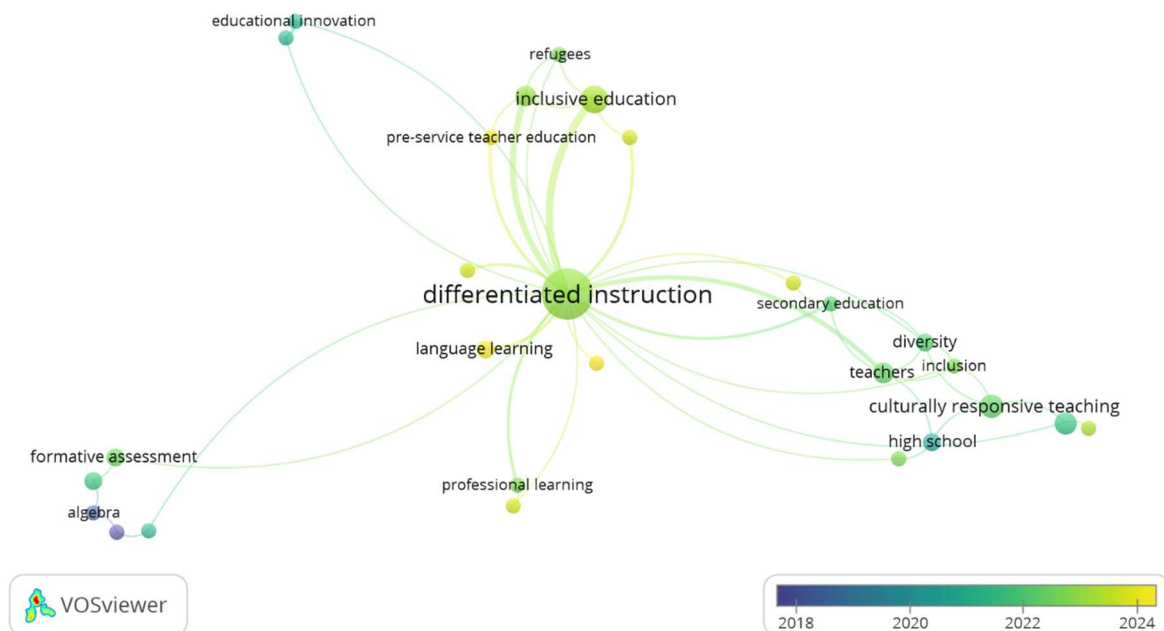


Fig 7. Thematic Evolution through Co-Occurrence Analysis

4. Discussion

The results of bibliometric analysis in this study show that research on differentiated instruction in secondary education has increased sharply over the past decade. The surge in publications after 2019 confirms that differentiated instruction is increasingly being positioned as a key pedagogical approach in systemic efforts to provide inclusive, adaptive, and learner-centered learning. This direction of development is consistent with the theoretical basis put forward by Tomlinson [42], which emphasizes that differentiated instruction is essentially a flexible instructional process that adapts to students' readiness, interests, and learning profiles. The high level of attention given by researchers to this issue indicates that the challenge of diversity among students in modern classrooms requires instructional strategies that are no longer uniform and linear. However, the resulting publication map reveals a fairly strong geographical imbalance, with most scientific works on differentiated instruction still concentrated in countries with large research capacities. This imbalance confirms a global phenomenon that is also highlighted by Asare et al. [43]. The distribution of educational research is still biased towards certain countries, meaning that perspectives from other regions are not proportionally represented. This gap has resulted in a lack of diversity in differentiated instruction approaches that take socio-cultural dimensions into account. In fact, the effectiveness of differentiated instruction is often greatly influenced by cultural context. This is confirmed in research on communication barriers and cultural knowledge deficiencies among Indonesian adolescents, which shows that cultural context greatly determines the quality of learning interactions [44]. Thus, the uneven publication map indicates that research on differentiated instruction is still far from comprehensive global representation.

The intellectual structure of the research identified through cocitation analysis shows a clear separation between conceptual research clusters and research clusters focused on classroom implementation. Conceptual clusters refer extensively to the basic theoretical foundations of differentiated instruction, such as the work of Tomlinson [42], while the implementation cluster emphasizes empirical studies on the application of differentiated instruction in various school contexts, as described by Suprayogi et al. [45] and van Geel et al. [46], which documents the complexity of practices in the field. This separation shows that the transition from theory to practice has not been entirely smooth. Teachers often understand the concepts but find it difficult to apply them consistently due to the complexity of the classroom, time constraints, and lack of organizational support. This confirms the gap between teacher preparation and implementation demands, which has also been criticized by Langelaan et al. [47] and Smets & Struyven [48]. Thus, differentiated learning faces serious challenges in bridging the theoretical and instructional practice domains. The results of the co-occurrence analysis reveal that the research theme has evolved from a basic study of the principles of differentiation to contemporary pedagogical issues such as inclusive education, cultural diversity, formative assessment, teacher collaboration strategies, professional development, and technology integration. The interconnection of keywords such as inclusive education, culturally responsive teaching, assessment, and teacher collaboration shows that the scientific community increasingly understands differentiated instruction as an approach that is not only pedagogical but also social. This is in line with Adebisi [49]. Differentiated instruction is an important mechanism for ensuring fairness, equality, and access for all students. In addition, research Pozas et al. [50], Differentiated instruction contributes to student well-being, social acceptance, and academic self-concept, confirming that differentiation has a multidimensional impact that goes beyond academic outcomes alone. The development of this theme is also in line with the needs of 21st-century education as outlined by Blyznyuk et al. [51], emphasizing the need for pedagogical adjustments to align with the characteristics of digital learners.

These findings also emphasize that the integration of technology in education appears to be increasingly influential in the direction of differentiated instruction research. Although not directly discussing differentiation, research trends regarding artificial intelligence and project-based learning in education indicate significant opportunities to optimize differentiated instruction through data-driven approaches and automated personalization

[53, 54, 55]. This opens up new avenues of research at the intersection of differentiation, technology, and learning analytics. The patterns of scientific collaboration identified through bibliometric results also show that educational research networks are forming increasingly hierarchical and regionally segmented structures, as noted by Gu & Liu [55] and Fu et al. [56], so that connectivity and knowledge exchange across regions still need to be strengthened. The findings of this study also reveal a number of important gaps in the global literature on differentiated instruction. First, research is still dominated by short studies and descriptive studies, so that longitudinal evidence on long-term effectiveness is still very limited. Second, the integration of cultural literacy and differentiated instruction has not been explored empirically, even though cultural context has been shown to significantly influence learning interactions. Third, most studies only observe teacher implementation, while studies on school leadership that supports a culture of differentiation are still minimal, even though Tanzi & Hermanto [57], the importance of culturally responsive leadership. Fourth, although differentiated instruction is aligned with the goals of quality education as formulated in SDGs 4, research that explicitly links differentiation with SDGs 4 indicators is still very rare. Fifth, the integration of smart technology in differentiated instruction has not been the main focus of studies, even though its relevance and potential are increasingly clear in the context of global digital education transformation. Thus, this study makes a significant contribution by mapping the growth patterns, intellectual structures, and thematic directions of the global development of differentiated instruction in secondary education. These findings highlight the complexity and dynamics of the research, while identifying gaps that need to be filled by future research, particularly regarding the integration of cultural contexts, the equalization of global perspectives, more applicable teacher training designs, and the strengthening of the relationship between differentiated instruction and education quality indicators within the framework of SDG 4. The bibliometric mapping produced in this study provides a strong basis for formulating a more comprehensive, holistic, and inclusive research agenda in the development of differentiated learning in the future.

Limitations

This study has several methodological and empirical limitations that need to be considered when interpreting the findings. First, the scope of the data depends solely on the indexing of one main database, so there may be relevant publications outside of this index that are not captured by the analysis. This limitation has the potential to produce representation bias, especially towards countries or institutions with lower journal indexing rates. Second, the bibliometric techniques used mainly focus on publication metadata, thus failing to capture the conceptual depth or methodological quality variation of the studies analyzed. Analyses such as co-citation and co-occurrence measure structural relationships between articles but do not always reflect substantive relationships or actual theories. Third, the mapping of international collaboration does not fully reflect scientific cooperation that occurs informally or through non-publication platforms, so that the global research network patterns displayed may be more limited than the complex collaborative reality. Fourth, this study does not assess the causal relationship or empirical effectiveness of differentiated instruction, as bibliometric data does not provide direct evidence regarding the quality of implementation or learning outcomes. As a result, the relevance of differentiated instruction to the fulfillment of SDGs 4 cannot be comprehensively evaluated and is based solely on thematic interpretation. Fifth, temporal limitations in the range of publications analyzed may affect the identified trends, especially on new topics that are rapidly developing. Considering these limitations, the findings of this study need to be supplemented with further qualitative or quantitative studies to provide a more in-depth and contextual picture of the global development of differentiated instruction.

5. Conclusion

This study provides a comprehensive mapping of the global development of differentiated instruction in secondary education through bibliometric analysis that reveals the dynamics of publications, dominant actors,

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intellectual structures, and thematic evolution over the past two decades. The results show that research on differentiated instruction has increased rapidly since 2019 and has increasingly taken on a strategic role in learning that is responsive to student diversity. These findings show that conceptual and empirical studies related to learning differentiation continue to develop, although the distribution of research is still concentrated in certain countries and does not yet fully reflect a global perspective. The intellectual structure analysis shows a separation between theoretical foundations and implementation practices, while the thematic analysis shows a shift towards issues of inclusion, diversity, adaptive assessment, and teacher professional development. Overall, this study confirms that differentiated instruction is increasingly seen as an important component in efforts to improve the quality of education and achieve equitable learning outcomes. This study has several limitations, particularly related to its dependence on a single database, the inaccessibility of unindexed publications, and the limitations of bibliometric analysis in capturing the methodological depth and empirical quality of each study. In addition, bibliometric data does not allow for direct analysis of the effectiveness of differentiated instruction in the classroom or assessment of its specific contribution to the achievement of quality education indicators. Future research needs to expand data sources, combine bibliometric analysis with systematic reviews or qualitative approaches, and broaden the exploration of cultural contexts, technology integration, and teacher capacity building strategies. Future studies also need to explore the empirical relationship between differentiated instruction, learning outcomes, and sustainable education development goals so that they can make a stronger contribution to policy and practice at the school and education system levels.

Declarations

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Author contributions

S and AEJKN designed this study with input from SP and AA. S, AEJKN, and SP determined the research procedures, while AEJKN and AA were responsible for data analysis, which was reviewed by S. This manuscript was drafted by S and AEJKN with critical revisions and contributions from SP and AA. All authors have read and approved the final manuscript prior to publication.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this article.

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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