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Differentiation, technology, creativity, and equity in gifted mathematics education: A systematic review

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ABSTRACT

Gifted students in mathematics possess advanced cognitive abilities that often require instructional approaches beyond conventional classroom practices. However, existing mathematics education practices frequently fall short in addressing both the intellectual and affective needs of this population. This study aims to systematically map and synthesize mathematics learning strategies for gifted students reported in the literature over the past decade. Employing a Systematic Literature Review (SLR) guided by the PRISMA protocol, this study analyzed 17 empirical articles published between 2015 and 2025 in Scopus-indexed journals. The analysis combined thematic synthesis and bibliometric techniques to identify dominant instructional approaches, emerging trends, and research patterns. The findings reveal that technology-enhanced learning and differentiated instruction are the most frequently adopted strategies, followed by creativity-oriented instruction, enrichment, self-regulated learning, and acceleration. In addition, recent studies increasingly emphasize equity-sensitive and culturally responsive approaches, particularly in addressing the needs of twice-exceptional students and those from diverse socioeconomic backgrounds. These results highlight the multidimensional nature of mathematical giftedness and underscore the importance of flexible, inclusive, and evidence-based instructional designs. This review provides a conceptual foundation for curriculum development, educational policy, and teacher professional development aimed at optimizing meaningful mathematics learning for gifted students across diverse educational contexts.

INTRODUCTION

Students with exceptional talents or intelligence, commonly referred to as gifted students, demonstrate distinctive cognitive characteristics, including advanced abstract thinking abilities, rapid learning speed, and flexibility in solving complex problems (Sheffield, 2017; Xu et al., 2024). In the context of mathematics learning, these characteristics often manifest as early mastery of symbolic structures, sensitivity to patterns, and creative approaches to non-routine problems. However, conventional mathematics instruction is frequently designed for average learners and emphasizes uniform pacing and procedural fluency, which may limit opportunities for intellectual challenge and deep conceptual engagement for gifted students. As a result, many gifted learners experience under-stimulation, reduced motivation, or a mismatch between their learning needs and the instructional practices provided in regular classrooms.

In response to these challenges, a wide range of mathematics learning strategies for gifted students has been proposed and investigated in the literature, such as technology integration (e.g.,

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GeoGebra) to enhance interactive conceptual understanding (Azimi et al., 2023), creativity-oriented instruction (Kozlowski & Chamberlin, 2019), and the use of mathematical history to foster conceptual understanding and motivation (Doğruer, 2024).. Empirical studies have reported positive impacts of these approaches on gifted students' conceptual understanding, motivation, creativity, and learning autonomy. However, despite the growing body of research on instructional strategies for mathematically gifted students, the literature remains fragmented, making it difficult for educators and policymakers to draw comprehensive, evidence-based conclusions. This fragmentation is particularly evident in the limited integration of instructional strategies with broader considerations such as equity, cultural context, and the diverse profiles of gifted learners.

Although many approaches have been developed, the existing literature still shows limitations in providing a systematic and comprehensive mapping of the diversity of mathematics learning strategies for gifted students. Most previous studies have focused on one or two instructional approaches in isolation and have not integrated their findings into a comprehensive synthesis. As a result, educators and policymakers often face difficulties in designing evidence-based learning interventions that are appropriate for the diverse characteristics of gifted students. In addition, social and cultural factors such as economic background, teachers' cultural beliefs, and educational access gaps remain significant challenges in implementing effective learning strategies, especially in various global contexts with limited resources (Xu et al., 2024; Allotey et al., 2024).

Furthermore, students who fall into the twice exceptional (2E) category, namely students who are highly intelligent but also experience learning difficulties such as dyslexia or processing disorders, are still not adequately accommodated in commonly applied learning approaches (Budínová, 2024; Alshareef, 2019). This indicates the need for learning strategies that are not only academically challenging but also inclusive of the varied profiles and needs of gifted students. To that end, learning designs for gifted students need to move beyond elitist approaches toward a pedagogical framework that is adaptive, transformative, and responsive to neuropsychological diversity in the gifted population.

In response to these limitations, this study conducts a systematic literature review (SLR) based on the PRISMA protocol to comprehensively map mathematics learning strategies for gifted students reported over the past decade (2015–2025). The review synthesizes empirical studies across multiple instructional categories, including differentiation, enrichment and acceleration, creativity-oriented instruction, self-regulated learning, history of mathematics integration, technology-enhanced learning, and culturally and equity-sensitive approaches. Through this approach, the study aims to provide a structured overview that can inform curriculum development, educational policy, and teacher professional development in diverse educational contexts (Tirri & Kuusisto, 2013).

While previous systematic literature reviews on mathematics learning for gifted students have predominantly relied on narrative or thematic syntheses to examine specific instructional approaches, they have rarely incorporated bibliometric analysis as a complementary perspective. As a result, existing reviews offer limited insight into the evolution of research themes, publication trends, and patterns of scholarly collaboration within the field. To address this gap, the present study integrates thematic synthesis with bibliometric analysis, enabling a comprehensive examination of both instructional strategies and the broader structural development of research on mathematics education for gifted students.

Identification of giftedness in the context of mathematics learning

Identifying gifted students in mathematics learning is an important contextual consideration, as it influences how mathematics learning strategies are reported, categorized, and interpreted in empirical research. In educational literature, gifted students are generally defined as individuals who possess exceptional intellectual potential, either in general cognitive abilities or within specific academic domains such as mathematics. Within the Differentiated Model of Giftedness and Talent (DMGT), giftedness is understood as innate ability that may be developed into talent through systematic learning experiences, practice, and environmental support (Gagné, 2011). In the context of mathematics learning, gifted students typically demonstrate high potential in numerical, symbolic, logical, and spatial reasoning.

Importantly, mathematical giftedness is not synonymous with high academic achievement alone. Previous studies indicate that students with advanced mathematical potential may not always exhibit outstanding performance on conventional assessments, partly due to identification practices that favor standardized learning patterns (Budínová, 2024). Commonly reported indicators of mathematical giftedness include rapid acquisition of complex concepts, abstract and symbolic reasoning, creativity in solving non-routine problems, and metacognitive awareness of problem-solving processes (Sheffield, 2017; Kozlowski & Chamberlin, 2019; Xu et al., 2024).

In this systematic literature review, the discussion of giftedness is intentionally limited to how gifted students are defined and identified within the reviewed empirical studies, as this directly informs the classification and interpretation of mathematics learning strategies. Rather than adopting a single universal identification criterion, the included studies employ diverse approaches, such as performance in advanced or non-routine mathematical tasks, cognitive or ability-based assessments, teacher nomination, participation in formal gifted education programs, or combinations of multiple measures. This operational perspective acknowledges the variability of identification practices across educational contexts and avoids equating mathematical giftedness solely with high academic achievement. Consequently, the findings of this review should be interpreted as a synthesis of mathematics learning strategies applied to students identified as mathematically gifted within their respective research settings.

The identification of gifted students is further complicated by the presence of twice exceptional (2E) learners, who demonstrate high intellectual potential while simultaneously experiencing learning difficulties such as dyslexia or processing disorders (Alshareef, 2019). In addition, students from low socioeconomic or culturally diverse backgrounds may be underrepresented due to bias in identification instruments or teacher perceptions (Allotey et al., 2024; Budínová, 2024). These issues are highlighted in this review insofar as they influence the design, accessibility, and inclusiveness of mathematics learning strategies reported in literature.

The role of teachers in implementing mathematics learning strategies

Within the scope of the studies reviewed, teachers are positioned primarily as mediators in the implementation of mathematics learning strategies for gifted students. Rather than being examined as a separate theoretical focus, the role of teachers is considered insofar as it influences how instructional strategies, such as differentiated instruction, enrichment, technology-enhanced learning, and creativity-oriented approaches, are enacted in classroom or programmatic settings. This positioning aligns with the view that giftedness can be transformed into talent through appropriate learning experiences and instructional environments (Gagné, 2007).

Several empirical studies indicate that the effective application of mathematics learning strategies for gifted students is associated with teachers' ability to adapt instruction, facilitate higher-order thinking, and respond to diverse learner profiles. In particular, adaptive and individualized instructional practices have been reported to support student engagement and participation when implementing differentiated and enrichment-based approaches (Topçu & Aktan, 2025). From this perspective, teachers function as contextual agents who shape the practical realization of the learning strategies identified in literature.

However, broader discussions concerning teacher professional development, curriculum policy, and systemic educational support are beyond the primary objective of this systematic literature review. Accordingly, these aspects are not examined in depth. Instead, this review focuses on mapping mathematics learning strategies as reported in empirical studies, while acknowledging the role of teachers as key facilitators in the implementation of these strategies across different educational contexts.

Research questions

Accordingly, this review does not aim to empirically identify gifted students, but rather to synthesize how indicators and dimensions of mathematical giftedness are reported and conceptualized across existing empirical studies. To gain a comprehensive understanding of mathematics learning strategies for gifted students, this study was formulated to address the following research questions:

1. What indicators and dimensions of giftedness are reported in the context of mathematics learning, and how do variations in gifted students' abilities relate to the instructional strategies applied?
2. How have mathematics learning strategies and approaches been applied in the learning of gifted students based on the latest literature findings?
3. How are thematic trends and developments in mathematics learning strategies for gifted students reflected in research results over the past decade?
4. How do keyword co-occurrence patterns in research on mathematics learning strategies for gifted students appear based on bibliometric analysis?

These research questions guide the systematic review process, including the identification, classification, and synthesis of relevant empirical studies on mathematics learning strategies for gifted students. This review contributes to the field of gifted mathematics education in three important ways: (1) it provides a systematic categorization of mathematics learning strategies for gifted students based on empirical studies published over the past decade; (2) it highlights equity-related gaps in the literature, particularly concerning twice-exceptional students and learners from diverse socioeconomic and cultural backgrounds; and (3) it maps thematic trends and research directions through bibliometric analysis, offering a comprehensive overview of how research on mathematics learning for gifted students has evolved over time.

METHODS

This research employed a Systematic Literature Review (SLR) approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. The use of this method ensures a structured, transparent, and comprehensive synthesis of studies concerning mathematics learning strategies for gifted students. An SLR facilitates the collection and evaluation of scholarly works that meet specific inclusion standards, thereby improving the reliability and replicability of the findings (Mengist et al., 2020). Following the PRISMA protocol, the review process was organized through a standardized procedure and validated checklist to ensure methodological consistency and rigor (Conde et al., 2020; Moher et al., 2010).

Data collection was carried out using Watase Uake Tools, a systematic search assistant aligned with the PRISMA protocol and directly integrated with the Scopus database. Scopus was selected as the sole database for this review because it provides broad interdisciplinary coverage and comprehensive indexing of high-quality, peer-reviewed journals in education, social sciences, and mathematics education. Previous methodological studies have indicated that Scopus offers sufficient coverage for conducting systematic reviews in education-related fields, particularly when the focus is on empirical and high-impact journal publications. Therefore, limiting the search to Scopus-indexed journals (Q1–Q4) was intended to ensure academic quality, consistency, and comparability across included studies.

The main search keywords were "gifted students AND mathematical", with a publication window spanning 2015–2025. In addition to automated searches, a manual search was conducted to identify relevant and recent publications that may not have been captured by database algorithms. Other databases, such as Google Scholar or Web of Science, were not included, as this review focused specifically on peer-reviewed Scopus-indexed journals to maintain methodological consistency and a clearly defined quality threshold.

To ensure the relevance and quality of the findings in this study, articles were selected based on specific criteria. Articles were included in this study if they met the following criteria: They are the results of empirical research, whether qualitative, quantitative, or mixed methods; Focus on gifted students in the context of mathematics learning (Dimitriadis, 2016; Sheffield, 2017); Discusses strategies, approaches, methods, or models of mathematics learning; Published between 2015 and 2025 in international Scopus-indexed journals (Q1–Q4); and be written in English with full-text access available.

Papers were excluded from the review if they met one or more of the following criteria: duplicate or repetitive records; publications not indexed in Scopus Q1–Q4 journals; absence of an abstract or full-text version; an exclusive focus on giftedness identification without connection to mathematics learning strategies; or classification as non-empirical works, such as opinion pieces,

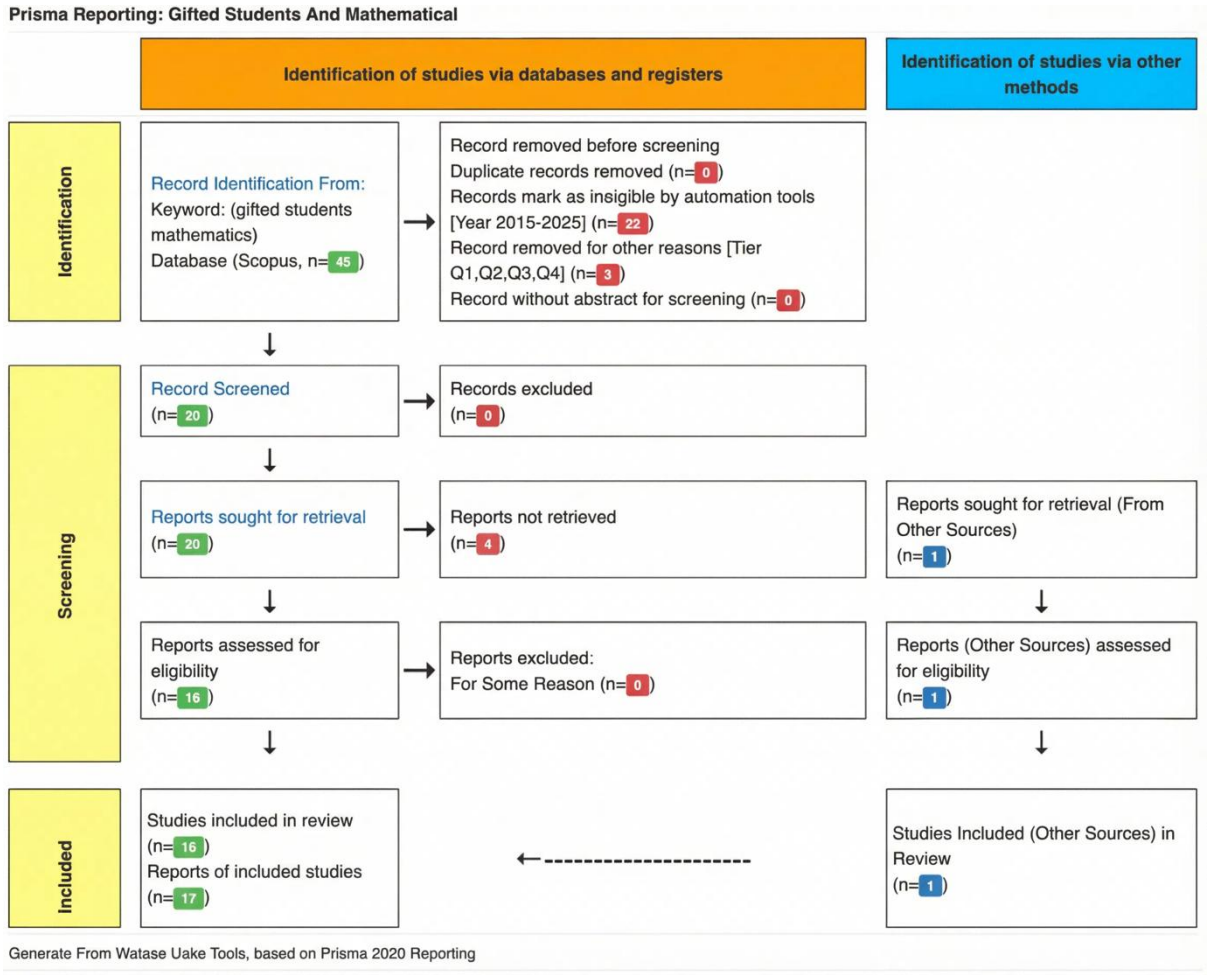

Figure 1. Article selection flowchart based on the PRISMA protocol.

editorials, non-systematic reviews, or conceptual papers lacking data-based evidence (Allotey et al., 2020).

The screening and selection procedures followed the PRISMA framework, encompassing the stages of study identification, preliminary screening, eligibility assessment, and final inclusion. The study selection process, conducted in accordance with the PRISMA protocol, is illustrated in Figure 1.

The initial database search yielded 45 records from the Scopus database. During the identification stage, 22 records were excluded for not meeting the publication year range or keyword relevance criteria, and an additional 3 records were excluded based on journal quartile criteria (Scopus Q1–Q4). The remaining 20 records proceeded to the title and abstract screening stage, during which all records were considered potentially relevant. At the eligibility stage, 4 full-text articles could not be retrieved and were therefore excluded. In addition, 1 relevant study was identified through manual searching. As a result, a total of 17 empirical studies met the inclusion criteria and were included in the final review.

Following the study selection process, data synthesis was conducted to analyze the characteristics and instructional strategies reported in the included studies. For the analysis of learning strategy frequency, a strategy-mention approach was adopted. Each included study was coded for all learning strategies explicitly reported, allowing a single study to contribute to more than one strategy category. Strategy frequency was therefore calculated based on the total number of strategies mentioned rather than the number of articles. This approach was used to reflect the multidimensional nature of instructional practices in gifted mathematics education, where multiple strategies are often integrated within a single study.

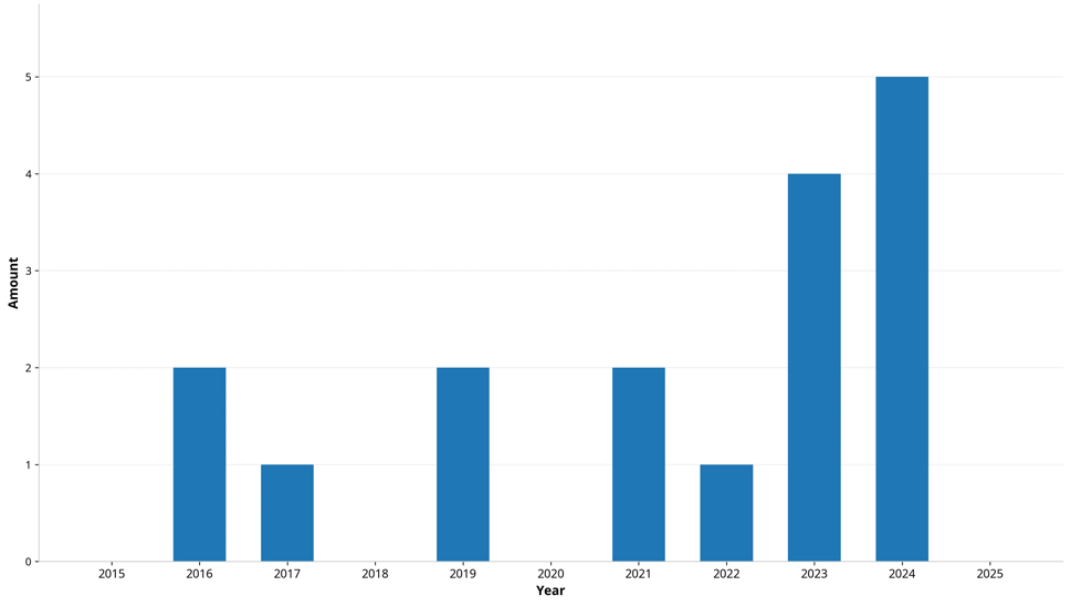

Figure 2. Annual distribution of the 17 Scopus-indexed publications on mathematics learning strategies for gifted students (2015–2025).

Although the final number of studies included is relatively limited, the 17 articles represent a diverse range of educational contexts, methodological approaches, and instructional strategies reported over a ten-year period. This diversity provides a sufficiently representative basis for identifying key patterns, thematic trends, and developments relevant to the objectives of this systematic review.

FINDINGS

A systematic literature search was conducted using the Scopus database through the Watase Auke Tools application, employing the keywords "gifted students AND mathematical" and restricting the publication years to 2015–2025. The selection process followed the PRISMA protocol and resulted in 17 articles that met the inclusion criteria for analysis in this study. The temporal distribution of publications included in this review is presented in Figure 2.

Figure 2 illustrates the annual distribution of the 17 articles included in this review based on their year of publication. The publication counts were derived from the Scopus database using Watase Auke Tools. Overall, the distribution indicates a gradual increase in the number of publications over the past five years, with a noticeable peak in 2024. This suggests increasing scholarly attention to mathematics learning strategies for gifted students in recent years.

The 17 reviewed studies originated from a range of countries, including the United States, Turkey, Iran, Canada, China, Italy, Croatia, Ghana, Greece, the Czech Republic, Israel, and Indonesia. The research designs employed across these studies varied considerably, encompassing quantitative, qualitative, mixed-methods, design-based research, case studies, and bibliometric analyses. This methodological diversity provides a broad overview of how mathematics learning strategies for gifted students have been examined across different educational and cultural contexts.

RQ 1: What indicators and dimensions of giftedness are reported in the context of mathematics learning, and how do variations in gifted students' abilities relate to the instructional strategies applied?

The synthesis of the 17 reviewed articles indicates that giftedness in mathematics is characterized by complex and diverse dimensions and is not uniformly manifested across all aspects of mathematical ability. Gifted students are reported to demonstrate particular strengths in one or more domains, such as geometric visualization, symbolic manipulation, mathematical modelling of real-life situations, and creativity in solving.

Common indicators of mathematical giftedness reported in the literature include advanced abstract and symbolic reasoning abilities, particularly among students who demonstrate rapid understanding of algebraic structures or formal mathematical logic (Xu et al., 2024). In addition, several studies report that gifted students tend to acquire complex mathematical concepts at a faster pace than their peers. For example, Azimi et al. (2023) reported accelerated learning progress among gifted students engaged with GeoGebra-based instructional prompts. This accelerated learning pace is frequently reported to be accompanied by higher levels of learning independence, including the ability to set learning goals, organize problem solving strategies, and evaluate learning outcomes, as reported in studies on self-regulated learning (Paz-Baruch & Hazema, 2023). Another commonly reported dimension is the ability to solve non-routine problems in original and creative ways, with gifted students often reported as demonstrating multiple solution paths and reflective explanations of their reasoning (Kozlowski & Chamberlin, 2019).

Despite these indicators, the identification of gifted students in mathematics remains challenging. Budínová (2024) highlights the risk of misidentification or non-identification arising from narrowly defined assessment tools and teacher bias toward conventional performance indicators. These challenges are reported to be particularly pronounced for twice exceptional (2E) students, learners who exhibit high mathematical potential alongside learning difficulties. Students with conditions such as dyslexia or ADHD are frequently reported as being overlooked in identification processes because their observable performance may not align with traditional expectations, despite evidence of exceptional strengths in specific mathematical domains.

Variations in gifted students' abilities are also reported to be associated with differences in the instructional strategies applied. Students demonstrating strong visualization and spatial reasoning skills are frequently engaged in learning environments that incorporate visual representations and manipulative technologies, such as GeoGebra (Azimi et al., 2023). In contrast, learners characterized by high levels of creative thinking and proficiency in solving open-ended problems are often associated with instructional approaches that emphasize open-ended tasks and the exploration of multiple solution strategies (Kozlowski & Chamberlin, 2019; Keleş, 2023).

Similarly, students who exhibit strong independence and metacognitive awareness are reported to benefit from instructional strategies that support self-management and autonomous learning processes. Xu et al. (2024) reported that project-based digital learning environments and adaptive online systems were associated with strengthened self-regulated learning capacities among gifted students. In addition, learning experiences such as mathematics camps (Aparicio et al., 2021) and instructional approaches integrating the history of mathematics (Karatas-Aydin & Isiksal-Bostan, 2022; Doğruer, 2024) have been reported to broaden the range of abilities that can be recognized and nurtured in gifted learners.

Overall, the reviewed studies report considerable variation in mathematics learning strategies applied to gifted students across different contexts. Technology-based and creativity-oriented approaches are among the most frequently reported strategies in literature, alongside differentiation, enrichment, and self-regulated learning. The distribution of these strategies varies across studies and educational settings, reflecting differences in instructional focus and contextual characteristics reported by the included research.

RQ 2: How have mathematics learning strategies and approaches been applied in the learning of gifted students based on the latest literature findings?

Based on the systematic synthesis of the 17 reviewed articles, a range of mathematics learning strategies and approaches have been reported in the literature on gifted education. To provide a structured overview, Table 1 presents the key characteristics of the included studies, including the authors and year of publication, educational level, sample size, gifted identification methods, country, study design, outcomes, and main findings.

Table 1
Characteristics of included studies on mathematics learning for gifted students

Author (Year)	Educational Level	Sample Size	Gifted Identification Methods	Country	Study Design	Outcomes	Main Findings
Azimi et al. (2023)	Secondary (Grade 10)	60 students	National gifted selection test and placement in specialized gifted school	Iran	Design Based Research	Learning achievement, higher-order cognitive outcomes (creativity), retention, student feedback	GeoGebra integrated with differentiated instructional prompts (ABPs and SBPs) improved gifted students' learning achievement, creativity, and retention, with stronger effects observed after prompt redesign
Vargas-Montoya et al. (2023)	Secondary (15-year-old students; PISA participants, Grade ≥7)	236,938 students from 10,213 schools	PISA mathematics proficiency levels (Levels 5 and 6 classified as gifted/top performers)	Multinational (44 countries)	Quantitative (cross-sectional, PISA data)	Mathematics achievement (PISA mathematics scores)	ICT use at school is positively associated with mathematics performance for gifted students but negatively associated for their non-gifted peers
Sheffield (2017)	Not specified (conceptual paper; K–12 context discussed)	Not applicable	Not specified (discussion based on theoretical and prior empirical literature)	United States	Conceptual / Theoretical analysis	Conceptual understanding of mathematical giftedness, creativity, engagement, and achievement (reported across reviewed programs and studies)	Common myths about mathematically gifted students hinder the development of creativity, engagement, and high-level mathematical achievement; effective instructional practices emphasize creativity, depth, and supportive learning environments
Erdogan & Yemenli (2019)	Primary / Lower secondary (Grade 5; 12-year-old students)	36 students	Cognitive abilities screening test followed by WISC-R intelligence test; placement in a gifted education center	Turkey	Qualitative (content analysis; interviews, metaphors, and student narratives)	Attitudes toward mathematics (emotional dimension, perceived competence, vision of mathematics)	Most gifted students exhibited positive attitudes toward mathematics; however, a substantial proportion showed unstable or negative attitudes. Students' emotions toward mathematics were strongly influenced by their vision of mathematics and classroom learning experiences.

Table 1. Continued

Author (Year)	Educational Level	Sample Size	Gifted Identification Methods	Country	Study Design	Outcomes	Main Findings
Aparicio et al. (2021)	Secondary (High school; Grades 9–12, ages 14–18)	1,388 students (988 treatment; 400 control)	Teacher nomination based primarily on high mathematics achievement, motivation, and teacher-assessed potential	Italy	Quantitative (Randomized Controlled Trial)	Mathematical problem-solving skills, personality traits (Big Five), academic career intentions	Participants in mathematics camps is associated with improved problems, solving skills, particularly in logic-based tasks, and positive short-term effects on personality traits (lower neuroticism, higher extroversion) and intentions to enroll in university
Irving & Oppong (2016)	Secondary (Grade 9 mathematics curriculum; PISA age 15 context)	Not applicable	Not specified (analysis focused on curriculum alignment rather than identification of individual gifted students)	Canada	Qualitative document analysis / curriculum alignment study	Curriculum suitability for gifted learners; expert-like thinking; intrinsic motivation; alignment with the Parallel Curriculum Model	A high performing general mathematics curriculum aligned strongly with the core component of the Parallel Curriculum but lacked sufficient emphasis on inquiry, identity, and practice elements required to fully meet the needs of gifted learners.
Kozlowski & Chamberlin (2019)	Not specified (discussion spans elementary to secondary contexts)	Not applicable	Not specified (discussion includes mathematically gifted students with or without formal identification)	United States	Conceptual literature review and theoretical discussion	Mathematical creativity, divergent thinking, student affect, engagement, high-level mathematical understanding	Creativity-based mathematics instruction (CBMI) emphasizes open-eneffectultiple-solution, and modelling tasks that support mathematical creativity and positive affect, thereby raising the learning ceiling for mathematically gifted students.
Dimitriadis (2016)	Primary (Elementary; ages 7–11, focus on Year 2, Year 5, and Year 6)	224 schools (questionnaire phase); 4 schools with multiple case-study classes (case study phase)	Achievement tests and teacher nomination (as used by participating in schools)	United Kingdom (England)	Qualitative multi-phase study (questionnaire survey and in-depth case studies)	Effectiveness of gifted mathematics provision; student achievement, motivation, attitudes; program defensibility and sustainability	Gifted mathematics programs showed some positive effects on achievement and motivation, particularly in pull-out groups; however, weak theoretical grounding, inconsistent identification practices, and limited teacher expertise undermined program effectiveness, efensibility, and sustainability.

Table 1. Continued

Author (Year)	Educational Level	Sample Size	Gifted Identification Methods	Country	Study Design	Outcomes	Main Findings
Paz-Baruch & Hazema (2023)	Secondary (Grades 11–12)	151 students	General intelligence test (Raven's Standard Progressive Matrices) combined with school achievement; gifted/high achieving defined as ≥95th percentile on intelligence and high STEM grades	Israel	Mixed methods (sequential explanatory design: quantitative questionnaires + qualitative interviews)	Self-regulated learning strategies, motivation (intrinsic/extrinsic goal orientation, task value, self-efficacy), SES differences	Gifted and high-achieving students reported higher motivation and greater use of self-regulated learning strategies than typical achievers, with SES moderating several motivations and SRL dimensions; gifted students from low-SES backgrounds showed particularly strong gains in motivation and SRL compared to their peers.
Calabrese et al. (2024)	Secondary (High school; entering Grades 10–12)	Secondary (High school; entering Grades 10–12)	Competitive-admittance STEM summer camp; selection based on admissions exam (Honors Camp Instrument), essay, and recommendation letters; top 16% admitted	United States	Qualitative (thematic analysis of semi-structured interviews)	Students' perceptions of mathematics (perseverance, performance, self-efficacy, enjoyment of content, social component, life relevance, adult influence)	High-ability male and female students reported largely similar factors influencing their perceptions of mathematics; six shared themes emerged across genders, with adult influence identified as an additional theme reported only by female students.
Allotey et al. (2024)	Lower secondary (Junior High School)	10 teachers (mathematics and science teachers from 6 junior high schools)	Not specified (teachers relied on culturally informed beliefs rather than formal identification procedures)	Ghana	Qualitative case study (semi-structured interviews and lesson plan analysis)	Teachers' cultural beliefs about giftedness, gender perceptions, spiritual/supernatural conceptions, instructional practices for gifted students	Teachers' beliefs about giftedness were strongly shaped by cultural, spiritual, and gendered perspectives, often leading to naive or tacit conceptions that constrained the use of evidence-based strategies such as differentiation and acceleration for gifted students.
Karatas-Aydin & Isiksal-Bostan (2022)	Primary (Grade 5; elementary level)	30 students	WISC-R intelligence test (IQ > 120) combined with aptitude tests; enrollment in a homogeneous private school for gifted students	Turkey	Qualitative (basic qualitative research; content analysis of students' video reflection papers)	Students' views on learning (cognitive outcomes), motivation, curiosity, attitudes toward mathematics, and understanding of the history of mathematics	History of mathematics–embedded videos functioned as both a cognitive and motivational tool, enhancing gifted students' curiosity, motivation, attitudes toward mathematics, and understanding of mathematicians, mathematical concepts, and the evolutionary nature of mathematics.

Table 1. Continued

Author (Year)	Educational Level	Sample Size	Gifted Identification Methods	Country	Study Design	Outcomes	Main Findings
Budínová (2024)	Primary to lower secondary (elementary school; follow-up into lower secondary / early high school)	2 students (two in-depth case studies)	Standardized mathematics talent tests (TIM3–5), IQ testing (IQ > 130 and > 140), pedagogical–psychological counseling assessment, teacher and parent reports	Czech Republic	Qualitative case study (two longitudinal case studies with interviews, observations, and a 1-year educational intervention)	Identification risks, development of mathematical thinking, use of problem-solving strategies, metacognition, socio-emotional experiences of gifted students	Gifted students with dyslexia and those with extremely high IQ are at high risk of non-identification in school settings due to behavioral, social, and assessment-related factors; targeted long-term interventions using nonstandard tasks supported the development of mathematical thinking, strategic reasoning, and metacognition, despite limited school-based support.
Xu et al. (2024)	Secondary (Senior high school; Grades 10–12)	510 students (mathematics-gifted students from 10 key high schools; cohorts 2018–2024)	Placement in experimental / competition classes of key high schools based on entrance examinations and school selection; participation in mathematics competitions	China	Quantitative (cross-sectional survey with correlational and causal mediation analyses)	Mathematics competition achievement; participation patterns in online vs. offline gifted education; educational equity indicators related to family background	Online gifted mathematics education expanded rapidly during the COVID-19 pandemic and reduced the correlation between family income and mathematics competition achievement; however, access to material resources (computers, smartphones, broadband) significantly mediated students' participation and outcomes, disadvantaging rural and low-income students.
Spagnolo & Nicchiotti (2023)	Primary to secondary (Grades 2–13; focus examples on Grade 10 / age 15)	Not applicable (secondary analysis of large-scale assessment items; 211 test items analyzed)	Not applicable (study focuses on gender differences in standardized mathematics test items)	Italy	Conceptual analysis and secondary data analysis (large-scale assessment item analysis)	Gender gap index (GGIk); item-level gender differences in mathematics performance	Gender gap index (GGIk); item-level gender differences in mathematics performance

Table 1. Continued

Author (Year)	Educational Level	Sample Size	Gifted Identification Methods	Country	Study Design	Outcomes	Main Findings
Jurić et al. (2021)	Primary (Grades 5–8; ages 11–14)	104 students (23 identified as gifted based on additional mathematics classes)	Enrollment in additional school mathematics classes (used as the operational definition of mathematical giftedness)	Croatia	Quantitative (educational data mining using stream mining and concept drift detection with decision tree models)	Accuracy of gifted student detection models; indicators of motivation and acquired mathematical knowledge derived from game interaction data	Stream mining models based on students' interaction with educational computer games were able to detect mathematically gifted students with high accuracy (approximately 93–96%), using features related to learning speed and motivation, demonstrating the feasibility of early, data-driven identification without traditional testing.
Doğruer (2024)	Primary (Grade 5; Science and Art Center – enrichment program outside regular school)	51 students (27 female, 24 male)	Anadolu Sak Intelligence Scale (ASIS); admission to Science and Art Centers by the Turkish Ministry of National Education	Turkey	Qualitative (descriptive and thematic content analysis; questionnaire + student reflections)	Students' motivation, curiosity, attitudes toward mathematics, perspectives on mathematics, understanding of the history and development of mathematics	History of Mathematics (HoM)–integrated activities increased gifted students' motivation and curiosity, provided new perspectives beyond routine problem solving, enriched understanding of the development of mathematics and mathematicians' lives, and supported differentiated instruction, although some students initially perceived HoM as unrelated to exam-oriented learning.

In this study, the learning strategies reported in the selected articles were categorized into six main groups: differentiation, technology, creativity, enrichment, self-regulated learning (SRL), and acceleration. Because several articles reported more than one strategy, the analysis was conducted based on strategy mentions rather than the number of articles. This allowed the frequency analysis to reflect the range of instructional approaches reported across the reviewed studies. Figure 3 shows the percentage distribution of learning strategies reported across the 17 included studies. A total of 22 strategy mentions were identified, as individual studies may report more than one instructional strategy. Accordingly, the percentages displayed in Figure 3 are calculated based on the frequency of strategy mentions rather than the number of articles.

As shown in Figure 3, technology-based strategies were the most frequently reported, accounting for 27.3% of all strategy mentions. These strategies include the use of software such as GeoGebra, e-learning models, and the integration of information and communication technology (ICT) in mathematics instruction for gifted students. Differentiation strategies were the second most frequently reported (22.7%), indicating a strong emphasis in the literature on adapting learning content, processes, and products to align with the individual characteristics of gifted learners.

Creativity-oriented strategies accounted for 18.2% of the reported mentions and were primarily described through open-ended problem-solving approaches and exploratory activities that were reported to encourage original mathematical thinking. Enrichment strategies represented

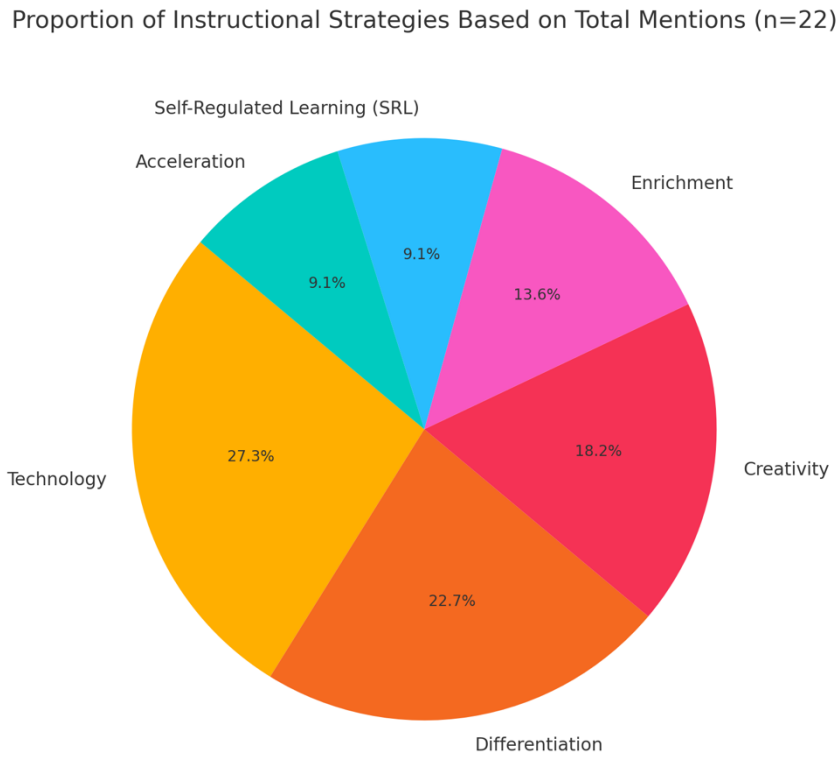

Figure 3. Distribution of mathematics learning strategies reported in the reviewed studies, with percentages based on strategy mentions.

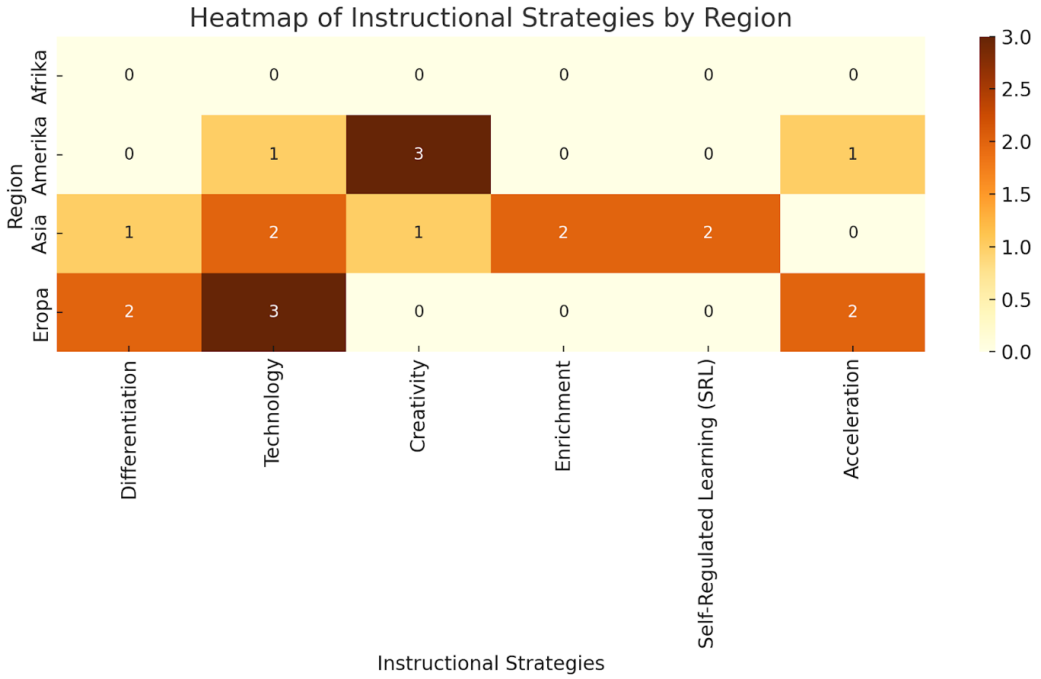

Figure 4. Heatmap of reported mathematics learning strategies by geographical region.

13.6% of the strategy mentions and were commonly associated with project-based enrichment activities, exposure to advanced mathematical topics, and the contextual expansion of learning experiences. Self-regulated learning (SRL) and acceleration strategies each accounted for 9.1% of the reported mentions, indicating approaches that emphasize learning autonomy and the pacing of curriculum content for gifted students.

Beyond identifying the most frequently reported learning strategies, this study also examines how these strategies are distributed across different geographical contexts. Figure 4 presents a heatmap illustrating the distribution of reported mathematics learning strategies across four geographical regions: Asia, Europe, America, and Africa. Regions were defined based on the country of origin of each included study. The heatmap values represent the frequency of strategy mentions per region, allowing a single study to contribute to multiple strategy categories. The data are not weighted by sample size or publication volume. The heatmap reveals notable regional variation in the mathematics learning strategies reported for gifted students.

In Asia, represented by Iran, China, Israel, and Turkey, technology-based strategies were frequently reported, alongside contributions related to self-regulated learning (SRL) and enrichment approaches integrating the history of mathematics. For example, studies from Iran reported the integration of GeoGebra and instructional prompts as being associated with enhanced conceptual understanding and creativity among gifted students (Azimi et al., 2023). Research from Israel highlighted an emphasis on strengthening self-regulation through SRL-oriented instructional designs (Paz-Baruch & Hazema, 2023), while studies from Turkey reported the use of historically contextualized instructional videos to support reflective and contextual learning experiences (Karatas-Aydin & Isiksal-Bostan, 2022).

European studies demonstrated a relatively balanced distribution of strategies, including technology use, acceleration, and differentiation. Research from the Czech Republic, for instance, reported the application of differentiation strategies designed to address the needs of twice-exceptional students (Budínová, 2024). More broadly, European literature reflects an orientation toward data-informed assessment practices, structured curricular frameworks, and sensitivity to learner diversity.

In North America, represented by the United States and Canada, creativity and acceleration strategies were frequently reported. This pattern aligns with longstanding traditions in gifted education within the region that emphasize developmental perspectives and individual differences. Kozlowski and Chamberlin (2019), for example, reported that creativity-based mathematics instruction emphasizing open-ended problem solving was associated with enhanced opportunities for mathematical creativity. In addition, Calabrese et al. (2024) examined differences in perceptions of mathematics among gifted male and female students, drawing attention to the relevance of gender-sensitive and affective dimensions in gifted education.

Africa contributes a complementary perspective through a study conducted in Ghana, which examined teachers' cultural beliefs about giftedness and gifted education. This research highlighted how cultural values and teacher perceptions may shape the ways in which giftedness is recognized and addressed within instructional contexts (Allotey et al., 2024). Although this study does not focus on specific instructional strategies such as technology or acceleration, it underscores the role of cultural paradigms and local contexts in influencing the direction of gifted education. From this perspective, epistemological awareness and shifts in teacher attitudes are suggested as important conditions for the meaningful implementation of instructional strategies.

RQ 3: How are thematic trends and developments in mathematics learning strategies for gifted students reflected in the results of research over the past decade?

Based on the systematic analysis of the 17 reviewed articles, several thematic tendencies and major trends were identified in the development of mathematics learning strategies for gifted students during the period 2015–2025. One recurring theme in the reviewed studies is the continued reporting of differentiated instruction and individualized learning approaches. In parallel, several studies report the integration of learning technologies in mathematics instruction for gifted students.

These strategies are frequently reported in the literature in relation to differences in learning pace, topic interest, and learning preferences (Erdogan & Yemenli, 2019; Budínová, 2024). In addition, the use of digital applications, online platforms, and educational software is reported not only for conceptual visualization but also for formative assessment purposes (e.g., eye-tracking techniques) and for supporting instruction through adaptive learning systems (Azimi et al., 2023; Xu et al., 2024; Jurić et al., 2021). Differentiation and technology integration are often reported together across the reviewed studies.

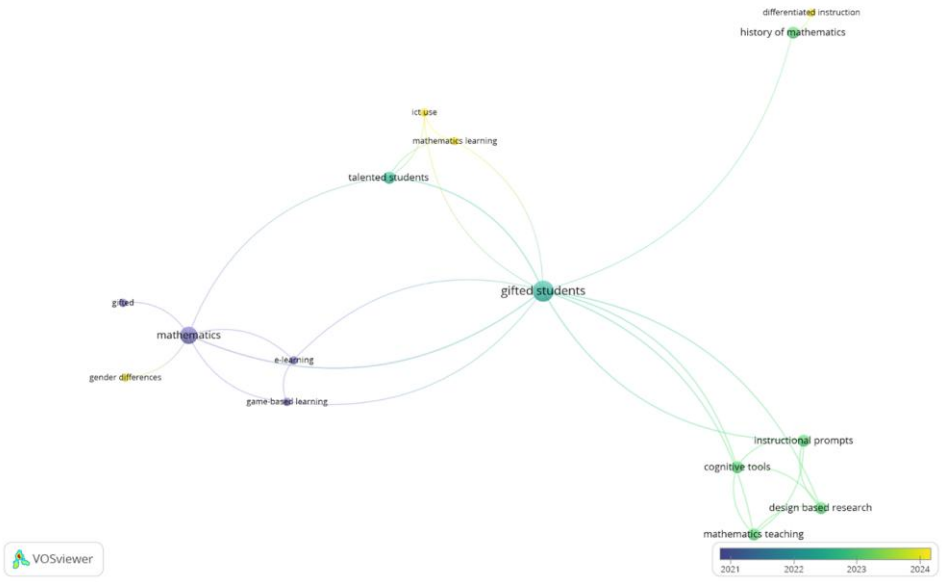

Figure 5. Keyword co-occurrence network of research on mathematics learning strategies for gifted students.

Creativity-oriented instruction continues to emerge as a central theme in research on mathematics learning strategies for gifted students. Creativity in this context is commonly framed as an important component of problem solving and higher-order thinking (Kozlowski & Chamberlin, 2019; Sheffield, 2017). Alongside this focus, several studies report the integration of the history of mathematics as a contextual instructional approach. These studies describe the use of historical perspectives in relation to students' conceptual understanding, curiosity, and motivation in mathematics learning (Karatas-Aydin & Isiksal-Bostan, 2022; Doğruer, 2024).

Another thematic area receiving increased attention in the reviewed studies is self-regulated learning (SRL), which is described in relation to students' abilities to plan, monitor, and evaluate their own learning processes (Paz-Baruch & Hazema, 2023). In addition to instructional and cognitive themes, several studies also report a focus on social and cultural dimensions of gifted mathematics education, including issues related to socioeconomic background, gender differences, teacher beliefs, and access to learning opportunities (Allotey et al., 2024; Calabrese et al., 2024; Spagnolo & Nicchiotti, 2023).

Finally, methodological diversification is identified as a notable trend in research on mathematics learning for gifted students over the past decade. While earlier studies predominantly employed qualitative or quantitative approaches, more recent research increasingly reports the use of mixed-methods designs, design-based research, bibliometric analyses, and advanced psychometric approaches such as Rasch model applications (Azimi et al., 2023).

RQ 4: What are the patterns of keyword co-occurrence in research on mathematics learning strategies for gifted students based on bibliometric analysis?

As a complement to the thematic synthesis, this study conducted a bibliometric analysis to examine patterns of keyword co-occurrence in publications addressing mathematics learning strategies for gifted students. The analysis was performed using VOS viewer software (Bilgic & Baloğlu, 2023). The keyword co-occurrence network derived from the 17 included Scopus-indexed articles published between 2015 and 2025 is presented in Figure 5.

Figure 5 displays the keyword co-occurrence network generated from the included studies. Keywords were extracted from the articles and analyzed using VOS viewer. In the visualization, node size represents keyword frequency, while link strength indicates the number of co-occurrences between keywords across publications. The keyword co-occurrence analysis identified a total of 15 main keywords that were interconnected across the reviewed studies. The keyword gifted students appeared as the most central node, showing co-occurrence links with terms such as mathematics,

gifted education, mathematics teaching, differentiated instruction, instructional prompts, design-based research, cognitive tools, mathematical creativity, game-based learning, e-learning, history of mathematics, ICT use, self-regulated learning, and socio-cultural beliefs. This network suggests that research on mathematics learning for gifted students extends beyond content-focused instruction and encompasses innovative pedagogical approaches, technological integration, socio-cultural considerations, and learning autonomy.

In addition, the appearance of keywords such as instructional prompts and design-based research indicates a growing scholarly interest in design-oriented learning environments and participatory research approaches. The observed pattern of keyword interrelationships further suggests that recent research trends in mathematics learning strategies for gifted students are oriented toward personalization of learning experiences, attention to mathematical creativity, the use of technological innovations, and the support of self-regulated learning. Collectively, these patterns reflect a gradual shift in literature from predominantly conventional instructional approaches toward more contextualized and learner-centered perspectives in gifted mathematics education.

DISCUSSION

The findings of this systematic literature review indicate that mathematics learning for gifted students requires flexible, multidimensional, and context-sensitive instructional approaches. Across the 17 reviewed studies, mathematical giftedness is not a uniform construct but is domain-specific and multidimensional, encompassing abstract reasoning, symbolic and spatial thinking, creativity, and high levels of metacognitive awareness (Sheffield, 2017; Budínová, 2024; Kozlowski & Chamberlin, 2019; Leikin, 2021). Consequently, foundational strategies such as differentiated instruction, enrichment, and acceleration remain central in gifted mathematics education, as they allow instructional depth, pacing flexibility, and responsiveness to individual learning profiles (Erdogan & Yemenli, 2019; Dimitriadis, 2016; Xu et al., 2024). Rather than being replaced, these approaches are increasingly adapted and extended to accommodate greater cognitive diversity among gifted learners.

Beyond foundational strategies, the synthesis of the reviewed studies reveals that creativity-oriented instruction emerges as a prominent theme across the analyzed studies. Learning designs that emphasize divergent thinking, non-routine problem solving, and reflective exploration support gifted students' intellectual engagement and deeper conceptual understanding (Kozlowski & Chamberlin, 2019; Assmus & Fritzlar, 2022). The integration of the history of mathematics further enriches learning by situating mathematical concepts within meaningful narratives, thereby fostering motivation and conceptual coherence (Karataş-Aydın & Işıksal-Bostan, 2022; Allotey et al., 2024). These approaches underscore a shift toward valuing learning processes, meaning-making, and intellectual curiosity alongside performance outcomes.

Technology-enhanced learning represents another significant dimension of contemporary gifted mathematics education. A substantial proportion of the 17 articles report the use of digital tools such as GeoGebra, game-based learning environments, and interactive online platforms to facilitate visualization, independent exploration, and adaptive learning aligned with the cognitive characteristics of gifted students (Azimi et al., 2023; Vargas-Montoya et al., 2023; Jurić et al., 2021). The prominence of technology-based strategies in the reviewed studies may reflect increased accessibility to digital tools, the expansion of online and hybrid learning contexts following the COVID-19 pandemic, and publication tendencies favoring technology-oriented interventions in high-impact journals. Importantly, the findings indicate that technology is most effective when integrated with pedagogical principles such as differentiation, creativity, and self-regulated learning, rather than implemented as a standalone instructional solution.

The bibliometric analysis further complements these thematic findings by revealing patterns of conceptual convergence and emerging research directions within the field. The keyword co-occurrence networks derived from the reviewed corpus indicate that concepts such as differentiation, technology integration, creativity, and self-regulated learning frequently co-occur, suggesting an increasing emphasis on personalized and learner-centered instructional designs in

gifted mathematics education. In parallel, the clustering of keywords related to socio-cultural factors and equity signals a growing, though still developing, research interest in addressing contextual and systemic influences on gifted students' learning opportunities. These bibliometric patterns reinforce the thematic synthesis by highlighting personalization, instructional innovation, and learning autonomy as interconnected focal points shaping contemporary research in the field.

At the same time, the synthesis highlights that the implementation and effectiveness of these strategies are strongly influenced by social and cultural contexts. Inequities in identification practices continue to disadvantage students from marginalized socioeconomic or cultural backgrounds and contribute to the underrepresentation of twice-exceptional learners whose mathematical potential may be obscured by learning difficulties (Budínová, 2024). Gender-related disparities also persist, with gifted girls often reporting lower mathematics self-concept and motivation despite comparable achievement levels (Calabrese et al., 2024; Spagnolo & Nicchiotti, 2023). Although equity-sensitive perspectives are increasingly discussed in the literature, relatively few empirical studies explicitly examine instructional strategies designed to address these disparities, indicating a gap between conceptual awareness and pedagogical implementation.

To ensure scientific transparency, it is necessary to clarify the scope and limitations of this review and to acknowledge potential sources of bias. This study was intentionally scoped to empirical and selected conceptual studies published in English-language, Scopus-indexed journals between 2015 and 2025. As a result, the findings primarily reflect trends and practices represented in peer-reviewed international literature, while excluding gray literature, non-English publications, and studies published in regional or non-indexed outlets.

Several methodological limitations should be acknowledged. First, restricting the review to Scopus-indexed journals may have led to the underrepresentation of relevant studies from certain geographical or linguistic contexts. Second, the relatively small number of included studies (17), resulting from the application of strict inclusion criteria, may limit the generalizability of the findings. Third, the exclusion of gray literature may have resulted in the omission of innovative instructional practices implemented in non-formal or practice-based educational settings. In addition, potential sources of bias include a publication tendency toward technology-oriented interventions and the limited empirical focus on equity-centered instructional strategies, which may influence the thematic emphasis identified in this review. Accordingly, the findings should be interpreted as indicative rather than exhaustive.

CONCLUSIONS

This systematic literature review highlights that effective mathematics learning for gifted students requires adaptive, creative, and inclusive instructional designs that respond to the multidimensional nature of mathematical giftedness. Synthesizing evidence from 17 Scopus-indexed studies published between 2015 and 2025, the review demonstrates that while differentiated instruction, enrichment, and acceleration remain foundational, contemporary practices increasingly integrate creativity-oriented learning, technology-enhanced instruction, self-regulated learning, and equity-sensitive perspectives.

The unique contribution of this study lies in its integration of thematic synthesis and bibliometric analysis, which constitutes a key methodological strength. This combined approach enables not only an in-depth synthesis of instructional strategies but also a broader mapping of research trends, thematic developments, and scholarly focus within the field of gifted mathematics education. By linking instructional practices with patterns of research evolution, this review provides a more comprehensive perspective than prior systematic reviews relying on a single analytical approach.

Despite these contributions, the findings should be interpreted in light of several limitations. The review was limited to English-language articles indexed in the Scopus database, and the relatively small number of included studies may restrict the generalizability of the conclusions. In addition, the exclusion of gray literature and the underrepresentation of certain educational contexts may introduce contextual bias.

Overall, this review offers a consolidated evidence base to inform curriculum design, teacher professional development, and future research in gifted mathematics education. Further studies are encouraged to expand database coverage, examine equity-focused and culturally responsive interventions, and employ longitudinal and context-sensitive designs to strengthen the empirical foundation of the field.

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Availability of data and materials	All data generated or analyzed during this study are available from the corresponding author on reasonable request.
Competing interests	The authors declare that they have no competing interests.

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