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Research Article

The Effects of Differentiated Mathematics Instruction on the Academic and Attitudinal Outcomes of Gifted Students: A Meta-Analysis

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Abstract

This meta-analysis investigates the impact of differentiated mathematics instructions on gifted students' academic achievement and attitudes. Such programs address advanced learning needs through curriculum compacting, acceleration, and enrichment. Synthesizing data from multiple studies, this analysis explores overall effectiveness, effects on attitudes, and moderating factors. Findings indicate positive effects on academic performance (effect size = 0.23) and attitudes toward mathematics (effect size = 0.34), though significant variability exists. Moderating factors included study origin and grade level; international and elementary-level studies showed greater academic gains, whereas high school students exhibited stronger improvements in attitudes. Results highlight the potential of differentiated instructions to support gifted learners academically and emotionally, emphasizing the importance of considering context, age groups, and cultural settings. The study calls for additional research into long-term impacts across diverse populations.

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Introduction

Mathematics education for gifted students has long been a priority for educators, researchers, and policymakers. These learners possess distinctive cognitive and affective needs that require tailored learning strategies to foster both intellectual growth and personal development (Hockett, 2009). Differentiated instruction—adapting content, process, and products to meet diverse needs—has proven especially effective in supporting gifted learners (Stott & Hobden, 2015). In mathematics, such approaches often involve enriched activities, complex problem-solving tasks, and varied teaching methods designed to extend students' capabilities (Landrum, 2001).

While the benefits of differentiated instruction are well established, its effectiveness can be influenced by broader contextual factors. Research underscores the need for culturally and linguistically responsive resources, such as providing rural English Language Learners with materials in their native language or developing programs that integrate the cultural heritage of native Hawaiian students (VanTassel-Baska & Hubbard, 2016). Similarly, offering new problem-solving strategies during the school day has been identified as a productive approach for gifted learners (Stott & Hobden, 2015). Collaboration models and resource consultation have also been shown to enhance service delivery and redefine educators' roles in supporting differentiated learning (Shore, 2021).

Despite these developments, challenges remain in implementing effective gifted education. Many students still lack sufficient classroom support or access to complementary services such as counseling (Antoun, 2022). The shortage of qualified teachers across all levels compounds these issues (Kuan et al., 2021). Additionally, gifted students face unique developmental and environmental challenges, highlighting the importance of schools proactively addressing these needs (Russell, 2018). These obstacles inevitably influence the success of subject-specific programs, making it essential to examine how they function in different contexts.

In the case of mathematics, the need for such examination is particularly urgent. Mathematics is not only a gateway subject for advanced study in STEM fields but also a domain where gifted learners often exhibit both exceptional potential and unique learning profiles (Szabo, 2024). Their advanced reasoning skills, rapid grasp of abstract concepts, and preference for complex, non-routine tasks mean that instructional approaches must go beyond standard acceleration or enrichment to sustain engagement and achievement (Leikin, 2013).

The impact of differentiated mathematics instructions on gifted students' academic achievement and attitudes toward mathematics has been widely studied, yet findings remain mixed. This variation in results highlights the need for a comprehensive analysis of existing evidence to better understand the true effectiveness of these programs for gifted learners. For example, studies of the Project M^2/M^3 curricula report significant achievement gains (Gavin et al., 2009; Gavin et al., 2013), whereas syntheses on other approaches—such as academic acceleration—show strong academic benefits but more mixed socio-affective outcomes (Steenbergen-Hu & Moon, 2011).

Despite the recognized value of data-driven approaches in guiding educational policy, the field still lacks comprehensive, detailed analyses to inform best practices (Plucker & Callahan, 2014). The ongoing debate between the merits of acceleration and enrichment further reflects this gap, as many studies lack the specificity needed to draw firm conclusions (Asher, 2003). Meta-analyses, which emphasize effect size rather than statistical significance, offer a valuable method for synthesizing such evidence (Asher, 2003; Warner, 2008). For instance, Kulik and Kulik's (1984) meta-analysis demonstrated the benefits of grouping in enrichment settings, yet few studies have directly compared enrichment with acceleration in mathematics for gifted students.

Against this backdrop, the present meta-analysis synthesizes existing research to evaluate the impact of differentiated mathematics instructions on gifted students' achievement and attitudes. Specifically, it addresses three research questions:

1. What is the overall effect size of differentiated mathematics instructions on gifted students' academic achievement in mathematics?
2. What is the overall effect size of differentiated mathematics instructions on gifted students' attitudes toward mathematics?
3. What factors moderate the effects of differentiated mathematics instructions on gifted students' achievement and attitudes?

By providing a comprehensive, up-to-date synthesis, this study aims to clarify the benefits and limitations of specialized mathematics instructions for gifted learners and to inform future educational practice and research in gifted education.

Literature Review

Conceptualizing Giftedness

Giftedness is not solely defined by high intellectual abilities; it also involves attributes such as motivation, persistence, and creativity. This broader understanding recognizes gifted individuals as those who exhibit exceptional skills across various domains, including mathematics, science, the arts, or leadership. Going beyond traditional measures like IQ, giftedness includes traits like innovation, enthusiasm, and specialized talents, reflecting the diverse and multifaceted nature of high potential (Gardner, 1983; Sternberg, 2000).

International and national frameworks reinforce this multidimensional view. For example, the National Association for Gifted Children (NAGC) defines giftedness as encompassing advanced cognitive abilities, creativity, and task commitment, which interact to produce high performance in specific domains (NAGC, 2019). Similarly, the OECD emphasizes that giftedness may manifest across intellectual, creative, social, and physical domains, and that appropriate educational provisions should nurture this potential (OECD, 2020).

When applied to mathematics learning, this definition implies that gifted learners often demonstrate exceptional reasoning, a rapid grasp of abstract structures, and a preference for complex, non-routine problems (Leikin, 2021). These traits shape both how they learn mathematics and the kinds of experiences that sustain their engagement (Leikin, 2011). Consequently, instruction should move beyond a one-size-fits-all model toward differentiated mathematics programs built around rich, challenging tasks and opportunities for multiple solution paths (Sriraman, 2003).

Differentiated Mathematics Instruction for Gifted Learners

To meet the advanced learning needs of gifted students, differentiated mathematics instruction employs strategies such as acceleration, enrichment, and curriculum compacting. These approaches are designed to deeply engage students with mathematical concepts, enhance their problem-solving abilities, and foster advanced reasoning. Key components include:

Curriculum Compacting – Eliminating unnecessary repetition to allow more time for advanced topics or deeper exploration (Reis & Renzulli, 1992; Renzulli & Reis, 2010).

Acceleration – Allowing students to progress more quickly through material or grade levels to match their faster learning pace (Kulik, 2004).

Enrichment – Providing richer, more complex learning experiences through diverse and challenging mathematical activities (Reis & Boeve, 2009).

Flexible Grouping – Adjusting group configurations based on students' evolving interests and abilities, encouraging collaborative problem-solving (Tomlinson, 2014).

Problem-Based Learning (PBL) – Engaging students in complex, real-world mathematical problems to develop critical thinking and creativity (Hmelo-Silver, 2004).

While each of these strategies addresses specific needs, their implementation and effectiveness vary widely. For example, curriculum compacting has been shown to improve achievement and engagement in mathematics among gifted students (Reis et al., 1993). Acceleration programs, including subject-based and grade-skipping approaches, have demonstrated significant positive effects on standardized mathematics test scores (Kulik & Kulik, 1992). Enrichment interventions, such as Project M^3, have been linked to gains in mathematical reasoning and problem-solving skills (Gavin et al., 2013). Flexible grouping has been found to foster peer collaboration and higher-level thinking in mathematics classrooms (Lou et al., 1996). Research on PBL with gifted learners suggests benefits in creative problem-solving and conceptual understanding (Mergendoller et al., 2006), although results are not universally positive and may depend on teacher expertise and classroom context.

Previous Research

Research has extensively explored the effects of differentiated mathematics instruction on gifted students, analyzing methods such as curriculum compacting, acceleration, enrichment, flexible grouping, and PBL. For example, Kulik (2004) found that students in accelerated programs outperformed their peers, while Reis and Renzulli (1992) reported that curriculum compacting improved both engagement and achievement. Maker (1982) concluded that enrichment activities boosted students' interest and motivation in mathematics. However, findings are not uniformly positive. While Hmelo-Silver (2004) found positive outcomes for problem-based learning, Gallagher et al. (1992) reported null or even negative effects in some cases, and more recent work likewise shows mixed results. For acceleration, a 35-year longitudinal study of mathematically precocious youth found no adverse long-term socio-emotional effects and supports acceleration as an effective intervention for high-ability learners (Bernstein, Lubinski, & Benbow, 2021). Qualitative research with mathematically gifted students describes perceived academic benefits of acceleration and highlights the importance of teachers' mathematical competence in sustaining challenge (Smedsrud, 2022). At the program level, a national analysis linked gifted program participation to only modest average gains in mathematics once selection is addressed (Redding & Grissom, 2021). Classroom-level interventions also show promising but context-dependent outcomes: differentiated mathematics instruction and gamified enrichment have been associated with improved attitudes and/or critical thinking among gifted students (Çayir & Balci, 2023; Yıldız & Yaman, 2024). A recent scoping review synthesizing 38 studies catalogued 15 approaches to differentiation for high-ability learners, underscoring variability in implementation and the need for more rigorous, domain-specific research in mathematics (Nicholas et al., 2024).

Further studies have examined how demographic and cognitive factors—such as gender, age, and mathematical ability—shape attitudes toward mathematics (Kurnaz, 2018). Research has also highlighted the benefits of integrating mathematics with arts and technology to improve classroom perceptions (Gadanidis et al., 2011). Additionally, psychosocial factors such as self-efficacy and motivation have been found to differentiate high achievers from underperformers (Dada & Akpan, 2019). Meta-analyses further support the role of targeted interventions. Assouline et al. (2015) and VanTassel-Baska et al. (2016) reported significant positive effects of acceleration and enrichment on both achievement and motivation, while Oğurlu (2021) emphasized their value in supporting social-emotional development.

Synthesis and Research Gap

Overall, the literature demonstrates that differentiated mathematics instruction—including acceleration, enrichment, curriculum compacting, flexible grouping, and problem-based learning—has the potential to enhance both achievement and attitudes among gifted learners. However, the evidence remains inconsistent due to variations in program design, implementation fidelity, and the context in which these strategies are applied. Moreover, relatively few studies have systematically compared the effects of different instructional approaches or investigated how learner characteristics and instructional practices moderate outcomes. This lack of clarity underscores the need for a comprehensive synthesis of the available research. The present meta-analysis addresses this gap by examining (1) the overall effect of differentiated mathematics instruction on gifted students' academic achievement, (2) their impact on students' attitudes toward mathematics, and (3) the moderating factors that influence these effects. By consolidating findings across diverse contexts, this study aims to provide clearer evidence to guide both classroom practice and policy in gifted mathematics education.

Methodology

Research Design

This study utilizes a meta-analytic approach to systematically analyze and combine the results of empirical research on how differentiated mathematics instructions affect the attitudes and academic performance of gifted students. By pooling data from multiple studies and calculating effect sizes, this method provides a thorough, evidence-based assessment of these programs' effectiveness, offering a statistically sound evaluation of their overall impact.

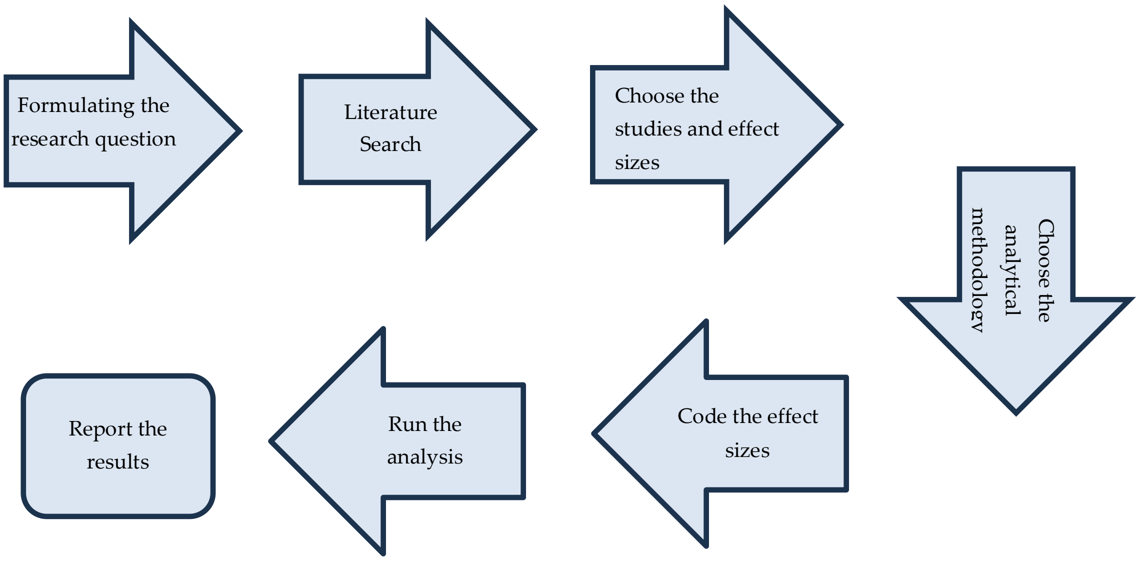

Figure 1. Workflow of the study

Inclusion and Exclusion Criteria

In conducting a meta-analysis, it is essential that the inclusion criteria for selecting studies are explicitly outlined in the protocol and aligned with the research objectives, as these safeguards against publication bias (Berman & Parker, 2002). For the present study, the selection of studies incorporated into the meta-analysis was guided by the following criteria:

1. *Databases in which the studies were found*

To conduct a comprehensive literature review, searches were performed across databases ERIC, ProQuest Dissertations & Theses, Google Scholar and YÖKTEZ utilizing keywords related (“gifted” and “mathematics achievement” and “mathematics attitude” and “differentiated instruction” and “acceleration”) to gifted education in mathematics and differentiated instruction methodologies.

The search process covered the studies published between 2000 and 2023 with database-specific Boolean operators applied. Titles, abstracts, and full texts were independently screened by two reviewers, and study quality was evaluated using a checklist. A Prisma diagram (Figure 2) was used to track study selection.

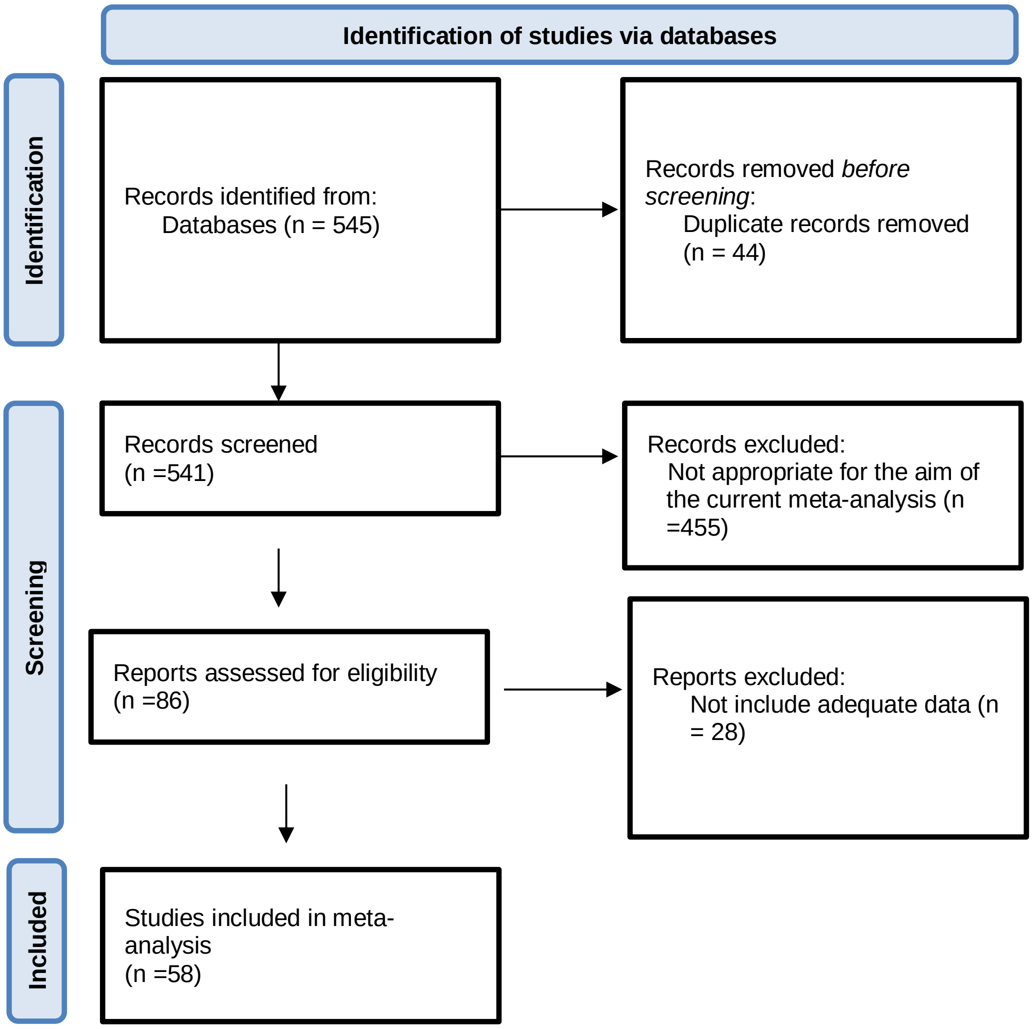

Figure 2. A Prisma diagram of the meta-analysis

2. *Accessibility of statistical data*

In the context of this meta-analysis, inclusion was limited to studies that reported sufficient quantitative data to allow for the computation of effect sizes (Cooper, 2017). Eligible studies were those employing both treatment and control groups for comparative purposes, as well as those incorporating pre-test and post-test measurements.

3. *Methodological appropriateness of the studies*

Studies included practice of differentiated mathematics instruction for K-12 and for college level gifted and talented students. The participant of the studies had to be defined as gifted and talented. Any study applies differentiated instruction to all other students except for gifted and talented are excluded.

Among the studies included in the meta-analysis, some examined both attitude and achievement (e.g., Akkaş, 2014; Altıntaş, 2009; Deringöl-Karataş, 2013; Eşsizoğlu & Çetin, 2022), while others (e.g., Chilton, 2001; Gavin et al., 2007, 2009, 2013) collected data over extended periods and/or across different educational levels, resulting in the calculation of distinct effect sizes. For this reason, each was treated as a separate study in the analysis.

Preparing the Coding Form

The study's coding protocol carefully records key aspects of the included research, such as the characteristics of the studies, experimental setups, contexts, participant demographics, and relevant variables, all following the guidelines set by Cooper (2017). The characteristics captured include the primary author, publication year, and type of study. The research methodology focuses on the types of comparison groups used, which are crucial for calculating effect sizes. Participant demographics are categorized by educational levels to ensure accuracy during analysis. Students were grouped based on their educational levels: kindergarten, elementary (K-5), middle (6-8), high school (9-12), and college+. When samples covered multiple categories, the group with higher grade levels was selected. Outcome measures again distinguish between academic achievement and attitudes, with effect sizes calculated to assess consistency and overall impact, underscoring the systematic approach taken to synthesize findings related to differentiated mathematics instructions for gifted learners.

Weights of the Studies

The meta-analysis necessitates verifying the normal distribution of effect sizes across selected studies to ensure statistical validity. This involves employing Normal Q-Q plots, Shapiro-Wilk test results, and calculating kurtosis and skewness coefficients to assess normal distribution. The Normal Q-Q plot compares the expected normal distribution values against the observed values, with a linear relationship indicating normalcy. However, the interpretation of Q-Q plot linearity remains somewhat subjective (Can, 2013). The distribution of effect sizes of the 58 studies is presented in Figure 3.

Upon reviewing Figure 3, it's evident that the effect sizes from the 58 studies align closely with a straight line, suggesting a normal distribution. This observation is supported by the Shapiro-Wilk test, indicating normal distribution of effect sizes (S-W = .126; $p > .05$), and by skewness (.312) and kurtosis (-.699) values within the accepted range for normal distribution (-1.96 to +1.96). Consequently, aggregating the effect sizes for meta-analysis is deemed appropriate.

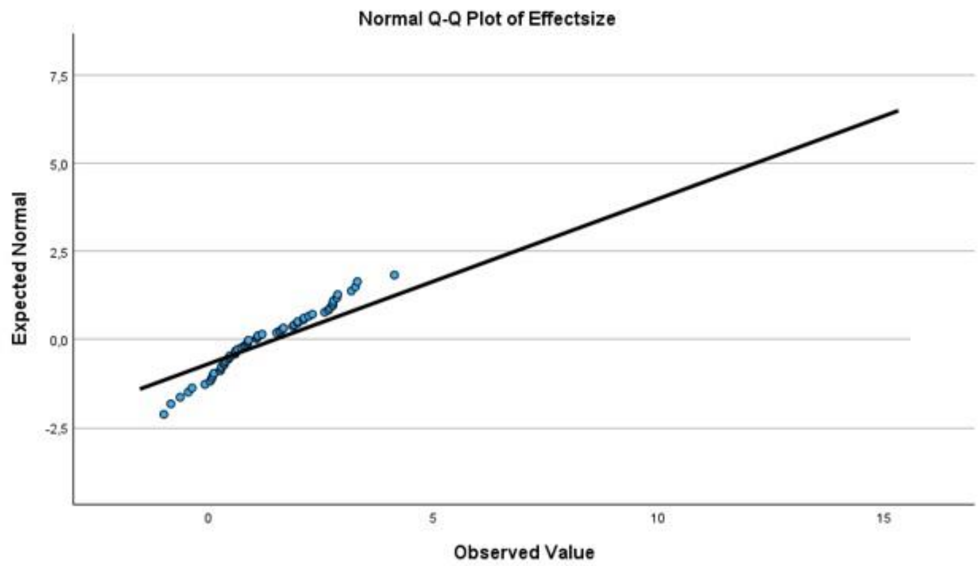

Figure 3. Normal distribution of effect sizes

In addressing the diversity of study sizes, from substantial cohorts like Gagne & Gagnier's (2004) research (n = 1625) to smaller scale studies such as Heilbronner et al.'s (2010) research (n = 8), a meticulous review under a random-effects model was imperative. The similarity between the studies is desired in a meta-analysis. This review ensures that the collective impact of studies, irrespective of their sample size, contributes equitably to the meta-analytic findings. The examination revealed a balanced weight distribution across studies, affirming the decision to retain all studies within the meta-analysis to preserve the integrity and comprehensiveness of the analysis (Dinçer, 2014).

Investigation of Publication Bias in Studies

Evaluating publication bias is crucial, as it can distort the results of a meta-analysis. To detect any potential bias, this study employed several techniques, including funnel plots, Rosenthal's Fail-Safe N Test, and Begg and Mazumdar's Rank Correlation method. These tools provide a reliable way to identify asymmetries that might indicate bias. Specifically, the funnel plot helps visualize how effect sizes are distributed around the overall average effect, with a symmetrical distribution suggesting that the sample of studies is unbiased. This thorough approach not only highlights the rigor of the methodology but also strengthens the credibility of the meta-analysis results. The scatterplot of the effect sizes for the studies included in the meta-analysis is shown in Figure 4.

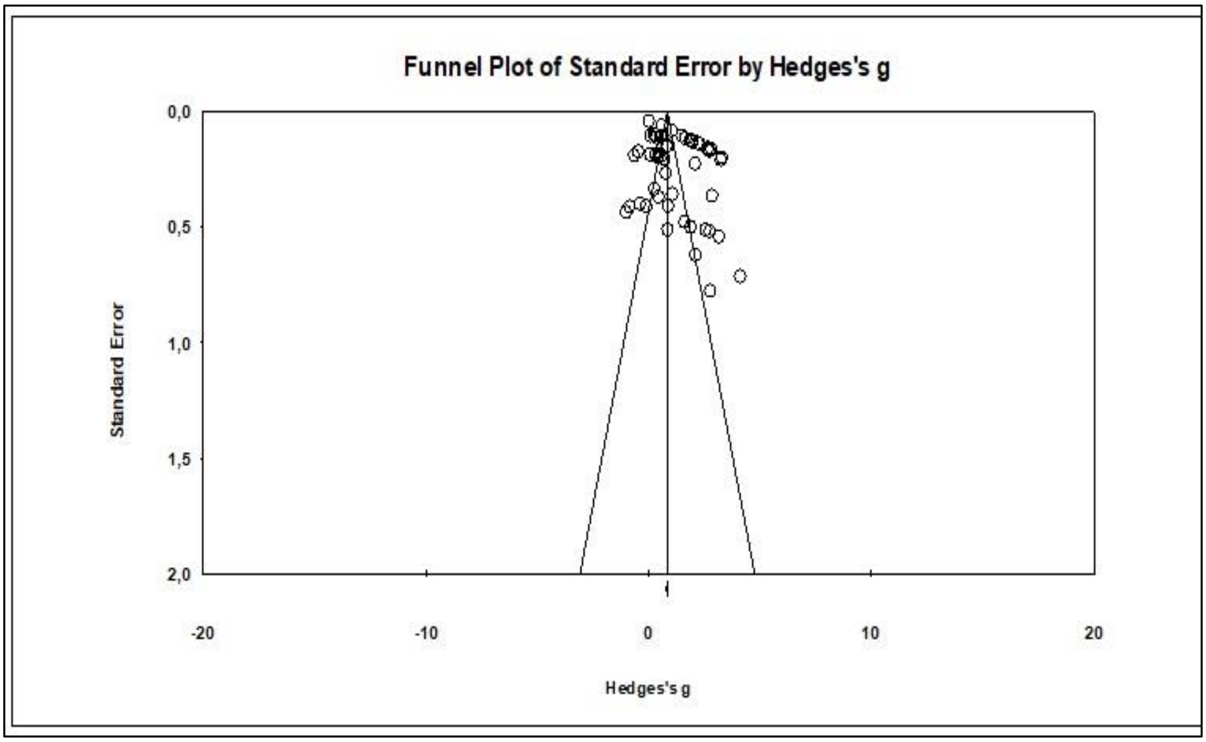

Figure 4. Funnel scatter plot

The analysis of the funnel plot revealed a generally symmetrical distribution, implying that there is no significant publication bias among the 58 studies reviewed. This symmetry around the central line, which represents the overall effect size, indicates a balanced sample of studies, with no overrepresentation of studies showing statistically significant results. However, the minor deviations from perfect symmetry suggest that further statistical tests for publication bias may still be warranted. Thus, specialized tests were employed to quantitatively assess the presence of bias, with their findings detailed in Table 1, providing a more nuanced understanding of the publication bias condition within the meta-analytic sample.

As indicated in Table 1, the results of Rosenthal's Fail-Safe N Test demonstrate that the outcome of the meta-analysis is statistically significant ($p = .000$). To render the significance of the meta-analysis result null, i.e., to achieve a p-value greater than .05, an additional 2948 studies with an effect size of zero would be required. The statistically insignificant result of Kendall's Tau coefficient obtained from Begg and Mazumdar's Rank Correlations (-.155 and $p = .09768$) is indicative of the absence of publication bias.

Table 1. Bias status of studies included in the meta-analysis: confidence tests and results

Confidence Tests	Confidence Tests Results	
Rosenthal's Fail-Safe N	Z-value for observed studies	45,81144
	P-value for observed studies	0,00000
	Alpha	0,05000
	Tails	2,00000
	Z for alpha	1,95996
	Number of observed studies	58,00000
	Number of missing studies that would bring p-value to > alpha	2948,00000
Begg and Mazumdar's Rank Correlations	Tau	0,15514
	Z-value for tau	1,65621
	P-value (2-tailed)	**0,09768**

Effect Size Calculation

This study computed standardized mean differences as Hedges' g with small-sample correction and pooled effects using an inverse-variance weighted random-effects model. To quantify the strength and direction of the relationships between variables, this study utilized the d-index (Cooper, 2017), which measures differences in group means. In cases where pre- and post-intervention assessments were used within the same cohort, these differences were expressed using the d-index and adjusted to Hedges' g (Rosenthal, 1991) to account for small sample sizes. For dichotomous outcomes, the log odds ratio was used to calculate effect sizes. Hedges' g values and transformations between effect size metrics were processed using the Comprehensive Meta-Analysis (CMA) software (Dinçer, 2014).

Heterogeneity Analysis

In meta-analysis studies, the homogeneity of effect sizes can be tested to determine the appropriate model. If the effect sizes are distributed homogeneously, the fixed-effects model is recommended; if not, the random-effects model is more suitable (Ellis, 2010). Given that the studies included in the present research are rooted in the social sciences, carried out in different countries and educational levels, and vary in design and measurement tools, the random-effects model appears more appropriate.

To further evaluate model selection, a Homogeneity Test was performed on the collected data. The test yielded a Q value that was statistically significant [Q = 1824,149, p = .000]. However, with a small number of studies included, the Q statistics may lack the statistical power to accurately detect heterogeneity (Huedo-Medina et al.; 2006). Also, p-value (.000) is smaller than .05, the findings indicate that the distribution of effect sizes is heterogeneous.

Therefore, the I^2 statistic was also examined to assess whether genuine heterogeneity exists among the studies. Unlike Q, I^2 is not sensitive to the number of studies or effect size values, making it a more reliable indicator of the proportion of total variation attributable to true heterogeneity (Dinçer, 2014). The I^2 value was calculated as 97,149%, indicating that nearly 95% of the observed variation across studies can be attributed to real differences rather than chance. According to Higgins and Thompson's (2002) classification, I^2 values of 25%, 50%, and 75% correspond to low, moderate, and high heterogeneity, respectively. Thus, the obtained I^2 value (97,149%) clearly indicates a very high level of heterogeneity. Furthermore, the p-value (.000) was again below the significance threshold of .05.

Taken together, these results ($Q = 656.412$, $p < .05$, $I^2 = 97,149$) provide strong evidence that the distribution of effect sizes is heterogeneous, supporting the use of the random-effects model for interpreting the meta-analysis results.

Findings

This meta-analysis examines the impact of differentiated mathematics instructions on gifted students, with a focus on their academic performance and attitudes toward mathematics. The study aims to address three key questions: What is the overall effect size of these programs on academic achievement? How do they affect students' attitudes? And what moderating factors influence these outcomes? The findings are presented in response to each of these questions, offering valuable insights into the effectiveness of differentiated instruction and highlighting the complex ways in which these programs shape the educational experiences of gifted learners.

Meta-Analysis of Academic Achievement in Mathematics

The range of effect sizes presented in Table 2, from -0.18 to 3.33, illustrates the varied impact of differentiated mathematics instructions on academic achievement among gifted students. Negative values indicate a detrimental effect, while positive values suggest beneficial outcomes, highlighting the diverse effectiveness of these interventions on gifted learners' academic performance.

Table 2. Effect sizes of studies of academic achievement

Study Name	Hedges's g	LL	UL	Weight(Tau)
Akkaş, (2014)	2,115	0,897	3,333	1,77
Altıntaş (2009)	0,881	0,079	1,682	2,13
Altıntaş (2014)-1	2,769	1,247	4,292	1,52

Altıntaş (2014)-2	2,573	1,569	3,576	1,96
Al-Zaobi (2014)	14,785	11,028	18,542	0,50
Brulles et al. (2010)	1,056	0,891	1,221	2,49
Brulles et al. (2012)	0,596	0,474	0,717	2,50
Casa vd. (2017)	0,250	0,055	0,445	2,49
Chilton (2001)-1	0,862	0,569	1,155	2,45
Chilton (2001)-2	0,824	0,532	1,116	2,45
Chilton (2001)-3	0,641	0,344	0,939	2,45
Chilton (2001)-4	0,725	0,320	1,129	2,40
Chilton (2001)-5	0,783	0,260	1,306	2,33
Deringöl-Karataş (2013)	-0,844	-1,653	-0,036	2,12
Eşşizoğlu & Çetin (2022)	2,102	1,658	2,546	2,38
Gagne & Gagnier (2004)	0,343	0,139	0,547	2,48
Gavin et al. (2007)-1	1,505	1,298	1,713	2,48
Gavin et al. (2007)-2	2,222	1,954	2,490	2,46
Gavin et al. (2007)-3	2,300	2,022	2,579	2,46
Gavin et al. (2007)-4	1,659	1,432	1,887	2,48
Gavin et al. (2007)-5	1,975	1,729	2,222	2,47
Gavin et al. (2007)-6	3,299	2,906	3,692	2,41
Gavin et al. (2007)7	2,690	2,381	3,000	2,45
Gavin et al. (2007)-8	2,843	2,520	3,166	2,44
Gavin et al. (2007)-9	1,979	1,720	2,239	2,47
Gavin et al. (2007)-10	2,655	2,331	2,978	2,44
Gavin et al. (2007)-11	2,752	2,420	3,083	2,44
Gavin et al. (2007)-12	3,255	2,846	3,665	2,40
Gavin et al. (2009)-1	0,281	0,083	0,479	2,49
Gavin et al. (2009)-2	0,584	0,372	0,795	2,48
Gavin et al. (2009)-3	0,373	0,149	0,598	2,48
Gavin et al. (2013)-1	0,113	-0,093	0,320	2,48
Gavin et al. (2013)-2	1,868	1,621	2,116	2,47
Guyton (2013)	0,088	-0,278	0,455	2,42
Heilbronner et al. (2010)	-0,373	-1,158	0,413	2,14
Kök (2012)	3,166	2,105	4,227	1,91
McCoach et al. (2014)	0,031	-0,052	0,115	2,51
Nance (2013)-1	0,461	-0,264	1,185	2,19
Nance (2013)-2	0,269	-0,393	0,932	2,24
Nance (2013)-3	1,083	0,382	1,784	2,21
Özçelik (2018)	2,754	1,735	3,773	1,94
Özyaprak (2012)	4,124	2,725	5,523	1,61
Ysseldyke et al. (2004)	0,433	0,040	0,827	2,42
Zaram (2017)	2,864	2,149	3,580	2,20

The findings show considerable variation in effect sizes reported across different studies on differentiated mathematics instructions for gifted students, with values ranging from -0.844 to 14.785. The study by Al-Zaobi (2014) reported the largest effect size, highlighting a notably positive impact, while Deringöl-Karataş (2013) found a slightly negative effect. On average, the effect size across all studies was 0.23, indicating a generally positive outcome (p=0.002), though there was significant variability. This suggests that, although differentiated instructions typically improve academic achievement, their effectiveness can vary considerably depending on the specific educational context and how the programs are implemented.

The distribution of the effect sizes of academic achievement studies is shown in the forest plot in Figure 3. The horizontal line represents the pooled effect size, and the vertical lines represent the 95% confidence intervals. The studies are ordered by their effect size with the most positive effects at the top and the most negative effects at the bottom.

The meta-analysis reveals a statistically significant positive average effect size (0.23, p=0.002) of differentiated instructions on gifted students' academic achievement, despite notable heterogeneity across studies, suggesting variability in program effectiveness. The forest plot's asymmetry hints at potential publication bias or quality disparities among studies.

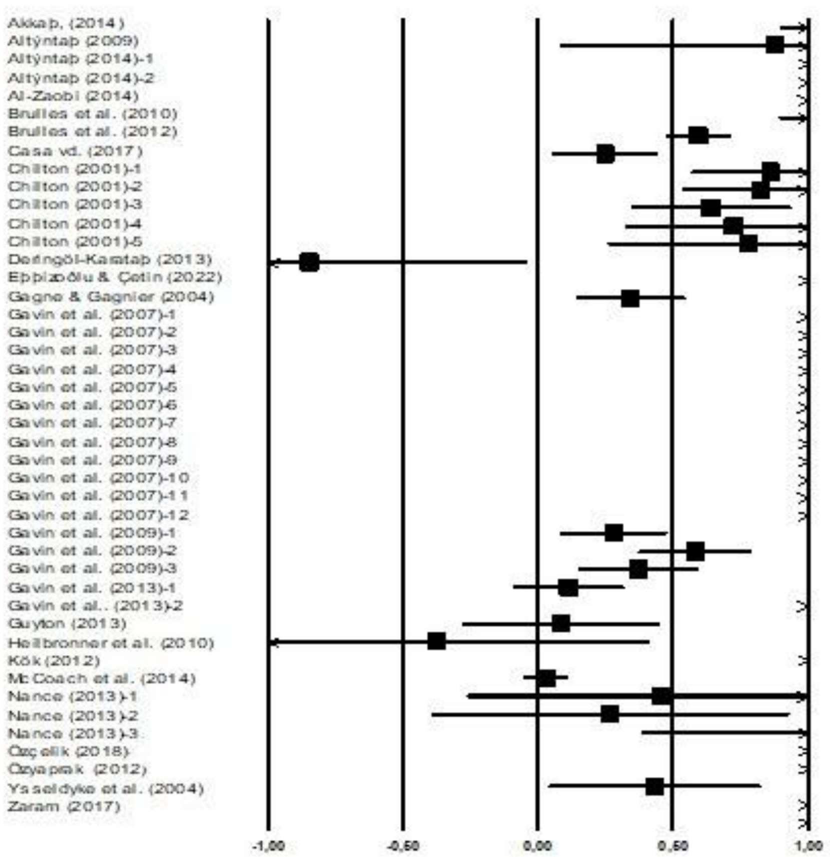

Figure 3. Distribution of effect sizes of academic achievement studies

In Table 3, the analysis further identifies study origin, grade level, and study type as moderators, indicating that these factors may influence the effect size of academic achievement outcomes, underscoring the complexity of assessing educational interventions' impacts.

Table 3. Moderators of effect sizes of academic achievement studies

	Effect size and 95% CI				Heterogeneity		
Moderator	**NS**	**LL**	**UL**	**P-value**	**Q-value**	**df (Q)**	**P-value**
Origin of Study							
Abroad	35	1,034	1,680	0,000			
Turkey	9	1,203	3,038	0,000			
Total between					2,369	1	0,124
Overall	44	1,136	1,745	0,000			
Grade Level							
College+	1	-1,158	0,413	0,352			
Elementary	23	0,965	1,864	0,000			
Elementary+Mi	3	0,350	1,085	0,000			
High	5	0,620	0,921	0,000			
Kindergarden	1	0,055	0,445	0,012			
Middle	11	1,965	3,600	0,000			
Total between					62,508	5	0,000
Overall	44	0,550	0,765	0,000			
Type of Study							
Article	27	1,245	2,019	0,000			
Thesis	17	0,784	1,517	0,000			
Total between					3,128	1	0,077
Overall	44	1,112	1,644	0,000			

The study's origin, grade level, and study type significantly influence the effect size of differentiated instructions on academic achievement. International studies showed greater effectiveness than those conducted in Turkey, potentially reflecting educational system differences or study quality. Elementary-level interventions were more impactful compared to high school, possibly due to younger students' openness to new learning methods. However, the distinction between articles and thesis did not significantly affect outcomes. This meta-analysis highlights the importance of context in evaluating the success of educational interventions for gifted students.

Meta-Analysis of Attitude for Mathematics

The effects sizes of studies of attitude in the meta-analysis are shown in Table 4.

Table 4. Effects sizes of studies of attitude

Study Name	Hedges's g	LL	UL	Weight(Tau)
Akkaş (2014)	0,867	-0,137	1,871	5,82
Altıntaş (2009)	1,574	0,694	2,453	6,32
Chilton (2001)	-0,459	-0,800	-0,118	8,34
Deringöl-Karataş (2013)	0,066	-0,707	0,839	6,76
Eşşizoğlu & Çetin (2022)	1,183	0,797	1,568	8,21
Guyton (2013)-1	-0,637	-1,012	-0,261	8,24
Guyton (2013)-2	0,586	0,212	0,960	8,25

Guyton (2013)-3	0,342	-0,027	0,711	8,26
Guyton (2013)-4	0,466	0,095	0,838	8,25
Özyaprak (2012)	1,090	0,258	1,921	6,51
Taş (2018)-1	-0,999	-1,856	-0,143	6,41
Taş (2018)-2	1,898	0,918	2,878	5,91
Taş (2018)-3	1,625	0,688	2,561	6,09
Taş (2018)-4	-0,085	-0,890	0,719	6,63

The study findings indicate a range of effect sizes from -0.999 to 1.898 for attitudes towards differentiated mathematics instructions, showcasing the varying impact of interventions. Taş (2018-2) reported the largest positive effect, while Taş (2018-1) observed a significant negative impact. With an overall effect size of 0.34, indicating a generally positive influence on attitudes, the data also reveals substantial heterogeneity among studies.

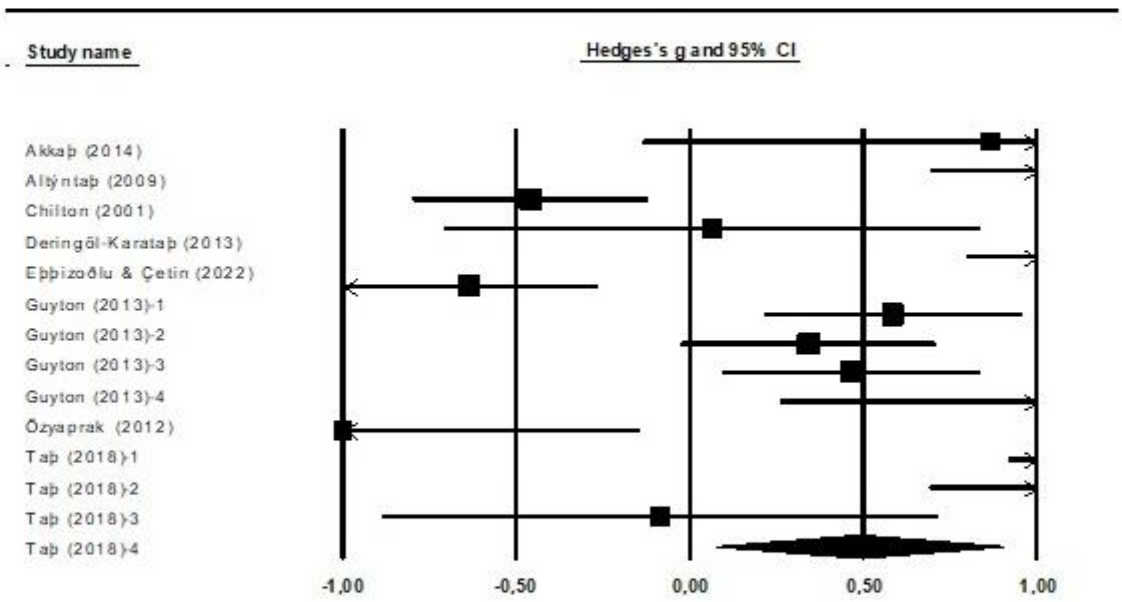

Figure 4. Distribution of effect sizes of attitude studies

An analysis of Table 5 examined the impact of programs designed to modify students' attitudes, with a focus on geographic origin and grade level as potential moderating factors. The results showed that the geographic location of the study did not significantly affect changes in student attitudes, indicating that these programs tend to have consistent effects across different educational environments.

Table 5. Moderators of effect sizes of attitude studies

	Effect size and 95% CI					Heterogeneity		
Moderator	**NS**	**LL**	**UL**	**Z-value**	**P-value**	**Q-value**	**df (Q)**	**P-value**
Origin of the Study								
Abroad	5	-0,436	0,552	0,230	0,818			
Turkey	9	0,213	1,369	2,684	0,007			
Total between						3,573	1	0,059
Overall	14	-0,008	0,743	1,919	0,055			
Grade Level								
College+	4	-0,355	0,735	0,682	0,495			
Elementary	3	0,026	1,475	2,030	0,042			
High	1	-0,800	-0,118	-2,638	0,008			
Middle	6	-0,082	1,753	1,784	0,074			
Total between						14,530	3	0,002
Overall	14	-0,317	0,199	-0,446	0,655			

However, grade level proved to be an important moderator, with high school students experiencing more significant shifts in attitude compared to their elementary or middle school peers. This may be due to older students being more open to diverse perspectives. These findings highlight the critical role that grade level plays in shaping the success of interventions aimed at modifying student attitudes.

The meta-analysis identified significant positive effects of differentiated programs on the academic achievement (pooled effect size = 0.23) and attitudes (pooled effect size = 0.34) of gifted students, despite considerable variability across studies. Two key moderators, the origin of the study and the students' grade level, were found to influence these outcomes differently. International studies and those focused on elementary students showed the largest improvements in academic achievement, while high school-level studies had a more pronounced impact on attitudes. These findings highlight the complex interplay of context and developmental stage in determining the success of educational interventions for gifted learners.

The results of the meta-analysis revealed a wide range of effect sizes across studies. For academic achievement, effect sizes ranged from –0.844 to 14.785, indicating substantial variability in how differentiated mathematics programs influence gifted learners. This wide distribution suggests notable heterogeneity in program implementation, study design, and contextual factors, which is expected in meta-analytic research but warrants careful interpretation. A small number of studies reported extremely large positive effects, such as

Al-Zaobi (2014), whose value of 14.785 stands out as an outlier compared to the general pattern. Such unusually high effects may disproportionately influence the pooled mean. While these studies were retained to preserve the integrity of the dataset, their presence highlights the potential value of conducting sensitivity analyses in future work, where recalculations excluding extreme cases could provide a complementary perspective on the robustness of the findings.

In addition, although the overall effect of differentiated instruction on attitudes toward mathematics was positive, not all studies reported favorable results. For instance, some investigations (e.g., Chilton, 2001; Taş, 2018-1) found negative or negligible changes in student attitudes. This indicates that differentiated mathematics programs may not uniformly enhance students' perceptions of mathematics, and in some cases, could even dampen motivation. These inconsistencies may reflect differences in program quality, teacher preparation, or alignment between students' needs and the instructional strategies employed.

Moderator analyses provided further nuance. For academic achievement, elementary students benefited the most, with effect sizes diminishing at higher grade levels. In contrast, for attitudes toward mathematics, the largest gains were observed among high school students. This divergence may be linked to developmental differences in how students experience differentiated instruction. Younger students may demonstrate stronger gains in achievement because foundational mathematical skills are still developing, making them more sensitive to enriched or accelerated opportunities. Older students, meanwhile, may show more pronounced attitudinal shifts, as differentiation intersects with their emerging academic identities, self-concept in mathematics, and motivation to persist in advanced studies.

Taken together, the findings suggest that differentiated mathematics programs can yield meaningful benefits for gifted learners, but the magnitude and nature of these effects are highly variable across contexts, grade levels, and outcome domains. This reinforces the need for continued research into the conditions under which differentiation is most effective, as well as the importance of reporting sufficient detail to allow for nuanced interpretation of outcomes.

Discussions

This meta-analysis confirms that differentiated mathematics programs yield statistically significant, albeit small-to-moderate, improvements in both academic achievement (g = 0.23) and attitudes toward mathematics (g = 0.34) among gifted learners. In the context of gifted education, even modest effect sizes can be meaningful, since gifted students are already high performers and small gains may translate into long-term advantages in STEM readiness and motivation (Hedges & Pigott, 2004; Kulik & Kulik, 1992).

The influence of moderators such as study origin and grade level on effect sizes points to the need for tailored approaches based on specific contexts and student demographics. The finding that studies conducted outside of Turkey show larger effect sizes aligns with previous research, which suggests that differences in educational systems, resource allocation, and cultural attitudes towards gifted education can significantly affect outcomes (Leana-Tascilar et al., 2016). These variations may also result from differences in methodologies or the level of emphasis on gifted education across different countries (Böttger & Reid, 2015). Regarding the effect of grade level, the analysis revealed that elementary students experienced greater gains in academic achievement compared to high school students (Haciömeroğlu, 2017). This contrasts with some literature, which often suggests more uniform effects across grade levels (Mohd et al., 2022). The stronger receptiveness of younger students to new learning experiences and the foundational nature of elementary education may explain this discrepancy (Haciömeroğlu, 2017). On the other hand, high school students showed more significant improvements in attitudes toward mathematics, a finding consistent with earlier research by Fadlelmula (2013).

The findings also highlight variation in effectiveness across program types. Acceleration, for example, has been shown in prior meta-analyses to consistently enhance achievement outcomes, though sometimes with mixed socio-emotional effects (Bernstein, Lubinski, & Benbow, 2021). Enrichment approaches, such as Project M^3, have been found to strengthen motivation and creative reasoning but show variability depending on program quality and teacher preparation (Gavin et al., 2013; VanTassel-Baska et al., 2016). Curriculum compacting studies suggest improvements in engagement and reduced redundancy (Reis et al., 1993). These distinctions underscore the need to tailor strategies to cognitive and affective profiles of gifted students rather than adopting a one-size-fits-all approach (Diezmann & Watters, 2000).

The heterogeneity observed in this meta-analysis highlights the variability in the impact of differentiated programs across different settings and populations (Bal, 2016). Previous research also supports the significance of these findings. For instance, Whiston et al. (2011) found that studies with higher methodological rigor tend to report larger effect sizes, reinforcing the importance of research quality in assessing the effectiveness of educational interventions. Similarly, Hedges and Pigott (2004) emphasized the relevance of considering moderators in meta-analyses to account for the variations in effect sizes across different studies. The current study demonstrates how these variations are critical to understanding the overall impact of differentiated programs.

Taken together, this study demonstrates that differentiated mathematics programs are a worthwhile investment—not because they guarantee large effect sizes across the board, but because even modest, context-sensitive gains can substantially benefit gifted learners. Policymakers and practitioners should support systematic teacher training, provide resources for differentiated instruction opportunities, and design interventions that are developmentally appropriate. Future research should investigate the interaction of program type, teacher preparation, and learner characteristics to better explain the observed heterogeneity in outcomes (Whiston et al., 2011; Nicholas et al., 2024).

Implications for Future Research and Practice

The systematic review of the literature reveals a growing inclination towards enrichment programs for gifted and talented students. To augment the sample repository for future meta-analyses, the current study advocates for academic journals to mandate the inclusion of explicit data points such as mean, standard deviation, sample size, or effect size by authors. This requirement would substantially expand the data pool available for meta-analytical evaluation. The meta-analysis in this study focused on the mean difference approach. However, exploring other meta-analytic methods, such as correlational or combined approaches, is recommended to improve the validity of generalizations regarding effect size. Additionally, employing a broader methodology, like meta-regression, could provide a more detailed and nuanced understanding of the data.

The variations in effect sizes based on study origin and grade level emphasize the importance of examining the cultural and developmental factors that influence the success of educational programs for gifted students. These factors should be carefully considered by practitioners when designing and implementing differentiated programs.

Given the differing impacts across grade levels and geographical locations, future research should focus on longitudinal studies that track the long-term effects of differentiated programs throughout various developmental stages and cultural contexts. Additionally, research could investigate how specific components of these programs—such as teacher training, curriculum design, and student-teacher ratios—affect their overall effectiveness.

Practitioners should take these findings into account when creating programs for gifted students. Tailoring interventions to fit the needs of different age groups and incorporating cultural considerations can improve their effectiveness. Moreover, sharing successful practices and program outcomes across educational systems could lead to more informed and effective approaches on a global scale.

Conclusion

This meta-analysis demonstrates that differentiated mathematics programs exert positive effects on both achievement and attitudes of gifted students, though the magnitude of these effects varies considerably across studies. Such variability reflects differences in methodological approaches, program fidelity, and contextual implementation. Recognizing this heterogeneity is essential, as it reminds educators and policymakers that the effectiveness of differentiation is not uniform but depends on how and where programs are designed and delivered.

Compared with previous meta-analyses that examined acceleration or enrichment more broadly (e.g., Kulik & Kulik, 1984; Steenbergen-Hu & Moon, 2011; VanTassel-Baska et al., 2016), this study contributes a focused synthesis of differentiated mathematics instruction, incorporating both cognitive (achievement) and affective (attitude) outcomes. By analyzing moderators such as grade level, it offers new insights into developmental differences, showing that younger students tend to benefit more in achievement, while older students demonstrate stronger attitudinal changes. This dual focus strengthens the evidence base for designing interventions that are both academically rigorous and motivationally supportive.

In summary, the findings highlight that even modest improvements in achievement and attitudes are practically significant in gifted education, where the goal is to cultivate exceptional potential rather than remediate deficits. Differentiated mathematics instruction, when implemented with teacher preparation and attention to developmental needs, can be a powerful means of supporting gifted learners. This meta-analysis underscores the importance of moving beyond general advocacy for gifted education toward evidence-based, domain-specific strategies that ensure gifted students receive the challenge and support necessary to fully realize their potential.

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Author Contribution Statement

Şule ŞAHİN DOĞRUER: *Conceptualization, literature review, investigation, data collection, data analysis, writing, editing, and final approval of the manuscript.*

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