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Research Article

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The Effect of Mathematics Difficulty Intervention Programs on Mathematics Performance: A Second-Order Meta-Analysis

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Abstract

Determining and evaluating the effects of mathematics difficulty intervention programs designed for students with MD are important for guiding teachers, researchers, and policy-makers. In this context, this research examines the influence of MD intervention programs on students' mathematical performance. Between 2009 and 2022, a total of 13 meta-analytical studies have been conducted. The research is currently exploring the consequences of intervention efforts on students diagnosed with MD for this objective. The analysis of this effect size value employs a second-order meta-analytical approach. Upon concluding the analysis process, it has been determined that the effect of MD intervention programs on students' mathematical performance is of moderate magnitude (ES = 0.70). Further, it is found that the location that MD intervention programs comprise, publication period, and features of participants are variables that cause meaningful differences in students' mathematics performance. According to the study results, types of the program and school level are variables that do not cause any meaningful difference. However, the program of EI intervention has an important effect on the mathematics performances of individuals with MD. Obtained results and directions for forthcoming studies are discussed in the scope of this study.

Key Words

Intervention program • Mathematics difficulty • Mathematics performance • Meta-analysis

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Introduction

Mathematics difficulties (MD) affect the process of learning arithmetical skills. Students with MD could potentially encounter challenges comprehending basic numerical concepts, and arithmetical operations, and they might not have the intuition to comprehend numbers (Kelly, 2020). MD is a mathematical inefficacy that affects learning the concept of numbers, basic mathematical operations, articulation, and accurate and fluent calculation processes (American Psychological Association [APA], 2013). Moreover, the concept of Mathematics Disability (MD) is delineated as a condition characterized by suboptimal mathematical performance attributed to various factors, including inadequate learning, limited cognitive development, and sociocultural influences, as outlined by the American Psychological Association (APA, 2013).

Different use of terminology in research makes it difficult to compare and evaluate research results. While the term "mathematics difficulty" is commonly used in the USA, the term "dyscalculia" is preferred in the UK and Europe (Kelly, 2020). It can be said that the target research included in this study focus on students with some specific difficulties in mathematics (learning difficulty, dyscalculia, children with low performance, dyscalculia risk). On the other hand, as identification criteria used for determining participant students vary according to studies, the term "mathematics difficulty" is used in this study. Students with the risk of failure in mathematics, students diagnosed as "having difficulty in math", and students with low mathematics success are the groups that have the problem of MD (Geary et al., 2007).

It is reported that the frequency of MD in the UK is approximately 5% (Kelly, 2020). A similar ratio is determined (5, 7%) in a study including the evaluation of 2461 primary school students based on DSM-5 diagnosis criteria (Morsanyi et al., 2018). In their research, Butterworth et al. (2011) documented a prevalence rate ranging from 5% to 7% for math difficulties. When these values are taken into consideration, it can be said that the observed frequency of MD varies between 5-6% (Kaufmann & von Aster, 2012). Based on data derived from the year 2015, it was observed that in the global context, over 55% of adolescents enrolled in primary and secondary educational institutions fell short of attaining the minimum proficiency standards in both reading and mathematics, as reported by the United Nations (UN, 2018). On the other hand, according to the 2019 NAEP mathematics score assessments, both 8th graders (66%) and 12th graders (76%) did not reach the minimum proficiency standards in mathematics (NAEP, 2019). Reports indicate that individuals have difficulties in learning and performing math.

Mathematical skills have critical importance in individual life (Nelson & Powell, 2018). It can thus be said that low arithmetical skills might affect school success, spiritual well-being, and confidence of individuals (Fritz et al., 2019). Furthermore causes losing various job opportunities in the future. On the other hand, individuals who have these difficulties might not have the chance to carry out some daily activities in life (Benavides-Varela et al., 2020). This is why; math education should be presented to individuals with mathematics difficulties through efficient interventions that increase their success (Myers et al., 2021).

Students with MD have problems with basic and advanced mathematical concepts (Myers et al., 2021). These students are less successful with the concept of numbers and calculation skills throughout the primary school education process when compared to their peers with no mathematical problems (Stock et al., 2010). It is observed that the disparity between students with MD and their peers widens as they progress through higher grade levels. The phenomenon referred to as a cumulative deficiency manifests as an inability among students with Mathematics Disability (MD) to precisely apprehend the presented educational content (Bender, 2016). The complexity of the mathematics learning process intensifies as students transition from primary to middle school (Myers et al., 2021). Deficient learning that couldn't be removed during primary education might increase the problems that these students experience and have permanent impacts on mathematics success (Witzel & Little, 2016). When students with MD aren't supported with additional courses and educational intervention programs, they continue to stay behind their peers who have typical development (Wei et al., 2013). It becomes evident that the difficulties faced by these students persist and impact their achievements in fractions, algebra, and ratios (Powell et al., 2021).

Experimental studies focused on intervention programs have indicated that enhancing the mathematical learning outcomes of individuals with MD is feasible (Aunio et al., 2021; Wu et al., 2020). Furthermore, meta-analysis studies suggest the existence of various educational intervention programs designed for individuals with MD (Myers et al., 2022). In these studies, it is determined that such intervention programs support students' mathematical learning processes. Researchers reported some efficient intervention programs such as cognitive-based instruction, technology-based instruction, concrete representation abstract instruction, schema-based instruction, peer-assisted instruction, and explicit instruction. Both researchers and practitioners frequently appeal to meta-analyses for efficient educational interventions that can be used for students with Learning Disabilities (LD). In this regard, it can be noted that there has been an increase in the quantity of meta-analysis dedicated to students with MD, and they have been increasingly employed within the field (Nelson et al., 2022).

There are some recent meta-analysis studies about MD students and the efficiency of mathematics intervention programs on their learning abilities (Myers et al., 2022; Ran et al., 2021). In the course of these investigations, scholars computed a range of effect sizes, exhibiting variations from moderate to relatively substantial, with values spanning from g=0.57 to g=0.71. Different effect sizes indicate that there are differences in the impacts of mathematics intervention programs. The reason behind these effect sizes might be the differences between inclusion criteria. For instance, Myers et al. (2022) analyzed mathematics intervention programs designed for increasing the performance of problem-solving achievement of students with MD. Based on the findings from 36 intervention studies, there is a substantial and favorable effect size (g = 0.71).

Meta-analysis studies in the literature give important information about the efficiency of intervention programs developed for students with MD. However, different definitions of variables, study groups, and intervention groups make it difficult to reach an absolute result. Myers et al. (2022) concentrated exclusively on the problem solving abilities of individuals with MD, encompassing grades 4 through 12. They also analyzed studies that involve a specific age range. The researchers partially alluded to efficacious intervention programs targeting students at the primary school level. It can be said that there is a need for a detailed analysis that involves all education levels. Myers et al. (2021) analyzed interventions designed for increasing the academic performance of individuals with MD at the secondary school level in a math lesson. Interventions targeting primary and high school students with MD are excluded. Ran et al. (2021) centered their research on the effect of computer technology on mathematics achievement. Nonetheless, it is imperative to create distinct intervention programs specially to the requirements of these students. As students with MD are heterogeneous, different intervention programs that serve their specific needs and features are necessary. Jitendra et al. (2020) exclusively reviewed Tier 2 interventions; so other intervention programs that are efficient in teaching mathematical subjects to students with MD are excluded from the study. Jitendra et al. (2018) used cutoff scores to determine students with MD (students with scores lower than the 35 percentile). Although the cutoff score is common (Mazzocco, 2007), the use of specific scores in analyses might exclude students with MD. For instance, 10 and 50 percentiles are commonly used to determine students with MD risk (Nelson & Powell, 2018). A more comprehensive cutoff score can be determined to analyze students with MD risk.

It is necessary to design and implement high-quality and efficient education for students with MD to complete and support mathematics education (Myers et al., 2021). It holds significance to comprehend and assess the effects of interventions developed for individuals with MD on their mathematical succes. It is necessary to make a comprehensive synthesis by taking articles and grey literature into consideration.

When the literature is analyzed, it is determined that there is not found second-order meta-analysis focusing on intervention programs designed for growing the mathematics performance of individuals with MD. In this regard, it can be asserted that a second-order meta-analysis is indispensable for the critical assessment and evaluation of primary studies, thereby facilitating the determination of the effectiveness of intervention programs. Within the scope of this study, the aggregation and assessment of effect sizes derived from first-order meta-analyses yield more precise estimations. Additionally, second order meta analysis involves the assessment of the quality of first order meta analysis. Thirdly, the identification of effective intervention programs that enhance the mathematical performance of individuals with MD is expected to actually benefit the practices of policy-makers, researchers, and educators. Fourthly, it was determined if intervention programs meaningfully varied in terms of moderator variables (publication year, location, grade, intervention program, participant characteristics, and quality).

The core aim of this research investigation is to evaluate the influence of intervention initiatives developed for students with MD on their performance in mathematics. Furthermore, the effects of moderator variables (grade, location, report type, intervention, quality, and participants' characteristics) on the academic success of students with MD are another basic focus of the study. In this context, the aim of this study is to examine the influence of intervention programs for MD on the academic achievement of students. The below-mentioned questions are asked and analyzed for this purpose.

1. To what extent do MD intervention programs affect mathematics performance?
2. Do moderator variables influence the impact of MD intervention programs on mathematics performance?

Method

Research Design

In this research, the utilization of the second-order meta-analysis methodology is undertaken to scrutinize the impact of Mathematics Disability (MD) intervention programs on the mathematical performance of individuals. This method closely parallels the approach of first-order meta-analysis. The studies subjected to second-order meta-analysis processes are, in fact, meta-analysis research studies (Polanin et al., 2017). Essentially, a second-order meta-analysis is a technique used to amalgamate the results of first-order meta-analysis research (Schmidt & Oh, 2013). In simpler terms, it involves analyzing the findings of meta-analyses.

Data Collection

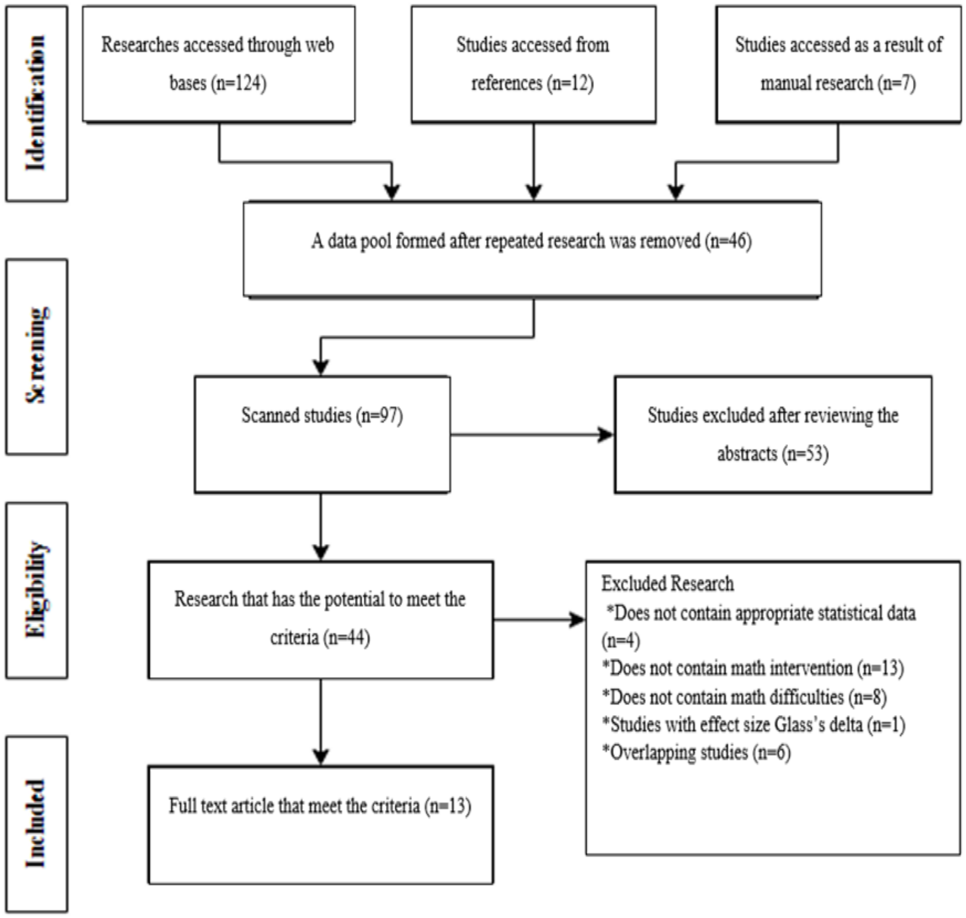
Data from the research is collected by using Wiley, Web of Science, Taylor & Francis, Sage Journals, Science Direct, and Scopus databases. A detailed electronic search is carried out by using these specific databases. The predetermined keywords are used while carrying out searches. In the first line of search, the keywords "learning difficulties/disabilities", "mathematics learning difficulties", "mathematics difficulties", "dyscalculia", "low achievement" and "low performance" are used. In the second line, "intervention", "instructional intervention", "mathematics intervention", "mathematics instruction" and "instruction strategies" keywords are used; and in the third line, "meta-analysis" and "systematic review" keywords are used.

On the other hand, manual searches were carried out in important journals in the LD literature. The data of the studies included in the research vary between 2009 and 2022. Since the oldest study included in the research was published in 2009, this year was preferred as the starting year of the screening.

At the end of the search procedure, a total of 143 studies are determined in the first phase. After this process, the studies that aren't relevant or repeat one another are excluded (n=46). In the next step, the reviewed studies are carefully analyzed according to their abstract section and the ones that aren't relevant are excluded (n=53). The full-text articles that are evaluated in terms of appropriateness are analyzed by considering inclusion and exclusion criteria (n=44). Out of these full-text articles, the ones that do not involve mathematics intervention (n=13), do not involve mathematics difficulty (n=8), proper statistical data (n=4), and overlapping studies (n=6) are excluded. The full-text articles that meet the criteria (n=13) are included in the second-order analysis. The review process is presented in Figure 1 with a PRISMA diagram.

Figure 1.

Data Collection Process



Inclusion Criteria

The following criteria were used for the studies included in the analysis:

1. The purpose of the research should be to analyze the effect of an intervention program developed for individuals with MD on their mathematics performance.
2. The intervention program used in the research should be clearly stated.
3. The participant group of research should include students diagnosed with LD and MD and students with MD risk.
4. Studies should have been published in 2009 and 2022 in English.
5. Studies should include statistical data sufficient for calculating effect size. The included studies and their characteristics in Table 1.

Table 1.

Included Studies and their Characteristics

Study	ES	LL	UL	k	Grade	Location	Report Type	Intervention	Quality	Bias	Year Range	Classification of the Participants
	1,22	0,80	2,15	11				EI				
Gersten et al. (2009)	0,47	0,25	0,70	12	K12	Global	Mixed	VR	High	Small	from 1971 to 1999	LD and MD
	0,14	-0,09	0,32	6				PAI				
Zhang, & Xin (2012)	2,63	1,96	3,31	16				EI	High			
	1,85	1,07	2,63	12	K12	Global	Mixed	CBI	High	NA	from 1996 to 2009	MD
	1,21	0,62	1,81	20				TBI	Median			
	0,50	0,30	0,70	10				EI				
Chodura, et al. (2015)	1,04	0,93	1,16	11	Elementary	Global	Article	CBI	High	No	-	At risk MD
	0,99	0,48	1,50	14				TBI				
	0,76	0,45	0,94	18				EI				
Dennis, et al. (2016)	0,82	0,42	1,22	4	Elementary	Global	Article	PAI	Median	NA	from 2000 to 2014	At risk MD
	0,39	0,15	0,64	9				TBI				
Jitendra, et al. (2016)	0,68	0,43	0,92	25	K12	Global	Article	VR	High	NA	Up to 2014	At risk MD
Stevens, et al. (2018)	0,85	0,56	1,14	25	K12	Global	Article	EI	High	No	from 1990 to 2015	MD
Küçükalkan,et al. (2019)	0,60	0,48	0,72	33	K12	Global	Mixed	CBI	Median	No	from 2007 to 2018	MD
	0,73	0,80	1,38	18				SBI				
Lein, et al. (2020)					K12	Global	Mixed		High	No	from 1989 to 2019	At risk MD
	0,28	0,06	0,50	11				CBI				

Table 1.

Continue

Study	ES	LL	UL	k	Grade	Location	Report Type	Intervention	Quality	Bias	Year Range	Classification of the Participants
Benavides-Varela, et al. (2020)	0,55	0,19	0,90	15	K12	Global	Article	TBI	High	No	from 2003 to 2019	MD
	0,56	0,29	0,84	28				TBI				
	0,45	0,10	0,79	11				VR				
Myers, et al. (2021)					Secondary	USA	Mixed		High	No	from 1978 to 2020	At risk MD
	0,31	-0,03	0,65	6				SBI				
	0,17	-0,07	0,42	4				PAI				
Ran,et al. (2021)	0,39	0,04	0,74	28	K12	Global	Article	TBI	High	No	from 2010 to 2018	At risk MD
	0,86	0,46	1,26	9				CBI				
Myers,et al. (2022)	1,18	0,86	1,50	29	Elementary	Global	Mixed	SBI	High	No	from 1992 to 2021	At risk MD
	0,71	0,22	1,20	17				CBI				
Dennis, et al. (2022)	0,49	0,38	0,64	44	Elementary	USA	Article	CBI	Median	NA	from 2005 to 2019	At risk MD

Interventions= CBI: Cognitive Based instruction; EI: Explicit Instruction; PAI: Peer-Assisted Instruction; SBI: Schema Based Instruction; TBI: Technology Based Instruction; VR: Visual Represantation, ** Classification of the Participants = MD: Mathematic Difficulties; LD: Learning Difficulties

Exclusion Criteria

Studies are excluded if they have the below-mentioned characteristics.

1. Studies that analyze an output different from the impact of developed educational intervention on mathematics performance (motivation, perception, etc.).
2. Studies with participants that are diagnosed with disabilities other than LD, MD, and/or MD.
3. Studies that have scores below 23 on the R-AMSTAR scale which is used for publication quality.
4. If Cooper and Koenka (2012) overlapping ratio of studies is below 25%, this indicates that the meta-analysis study is independent. If the overlapping ratio of meta-analysis studies is over 25%, current and more comprehensive meta-analyses are chosen and the other is excluded.

Overlapping Problem

One of the challenges inherent in second-order meta-analysis research pertains to issues of overlap, whereby multiple meta-analyses encompassing identical primary research studies are encountered. The task of conducting an analysis to identify and account for such overlap in this study has been undertaken by the first and second authors, and the resultant report of the overlapping analysis is delineated in Table 2.

Table 1.

Overlapping Analysis

Studies		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Benavides-Varela et al. (2020)	1	-																	
Chodura et al. (2015)	2	13	-																
Dennis et al. (2016)	3	7	12	-															
Dennis et al. (2022)	4	33	8	52	-														
Gersten et al. (2009)	5	-	-	-	-	-													
Jitendra et al. (2018)	6	-	-	-	30	-	-												
Kong et al. (2021)	7	-	-	27	27	-	-	-											
Küçükalkan et al. (2019)	8	-	-	-	9	-	-	-	-										
Lein et al. (2020)	9	-	4	15	33	-	-	-	-	-									
Myers et al. (2021)	10	-	-	-	14	-	60	-	-	10	-								
Myers et al. (2022)	11	-	-	-	-	-	-	-	-	-	-	-							
Ran et al. (2021)	12	-	-	-	-	-	-	-	-	-	-	-	-						
Stevens et al. (2018)	13	-	-	-	-	-	-	-	-	-	-	-	-	-					
Zhang & Xin (2012)	14	-	-	8	7	-	-	-	-	22	17	-	-	-	-				
Jitendra et al. (2016)	15	-	8	12	20	-	-	-	-	16	12	-	-	-	12	-			
Peltier & Vannest (2017)	16	-	-	33	28	-	28	-	-	-	-	-	-	-	-	-	-		
Shin & Bryant (2015)	17	-	-	-	-	-	-	-	-	-	47	-	-	-	-	-	-	-	
Zheng et al. (2013)	18	-	-	-	-	-	-	-	-	-	28	-	-	-	-	-	-	-	-

Note= *Italicized studies are excluded from the analysis due to overlap.*

Coding: The selected research is coded based on the issues mentioned below, and this coding is performed by both the first and second authors. The consistency of coding between the two authors is assessed using the reliability formula proposed by Miles and Huberman (1994). Coherence between coders is calculated to be .93. Codes that aren't coherent are discussed by all of the authors and the final decision is accordingly made.

Intervention program: Previous studies on the issue are taken into consideration in this study while encoding the intervention programs (Myers et al., 2015). Intervention programs are encoded in 6 different titles. Criteria that are taken into consideration while encoding intervention programs are presented below.

(a) Technology-Based Instruction (TBI): Studies based on computer-supported teaching and video-supported education.

(b) Cognitive Based Instruction (CBI): Studies that involve the use of articulation strategies for problem-solving, self-follow-up strategies and remembering which are cognitive or meta-cognitive.

(c) Schema-Based Instruction (SBI): Studies that are either based on scheme or scheme broadening (and transfer) instructions (Jitendra et al., 2018),

(d) Explicit Instruction (EI): When special education literature is analyzed, it can be seen that there is a general understanding that mathematics teaching should be open and systematic (Gersten et al, 2001; Swanson & Hoskyn, 1998). On the other hand, the terms should be used to define some teaching approaches (Gersten et al., 2009). To remove any misunderstandings, studies that have three components are encoded as open education (Gersten et al., 2009): (i) the teacher presents a step-by-step plan to solve the problem, (ii) the presented plan is specific for a series of problems and (iii) students use the plan presented by the teacher to solve the problem.

(e) Visual Representation (VR): Studies that involve concrete (for ex. manipulative), semi-abstract (for ex. pictures and diagrams), and abstract (for ex. symbols) representations in teaching mathematical concepts. These representations should be used by either teacher or student while solving problems to be able to encode the study visually.

(f) Peer-Assisted Instruction (PAI): Studies based on the learning process through cooperation among students are coded under this title. In peer-supported teaching, students not only carry out their learning activities but also they are responsible for learning how to work together with peers in group activities and how they should ask for help when needed (Polloway et al., 2013).

Participant characteristics

Students might have difficulty in learning mathematics; however, this situation doesn't mean that they have mathematics difficultyStudents afflicted by mathematics difficulties constitute a heterogeneous cohort characterized by challenges in the realm of mathematics (Nelson & Powell, 2018). In this respect, there is not a single common idea about defining students with MD (Myers et al., 2021). Students with MD are diagnosed with Legal Difficulty (LD) and have mathematics goals in the scope of an IEP (Individualized Education Program) (Myers et al., 2021).

Besides students with legal diagnoses, some students don't have a legal diagnosis but have low mathematics performance and MD risk. These students struggle to learn mathematics all the time (Swanson et al., 2015). They are regarded as students with MD risk according to the cutoff score (Nelson & Powell, 2018). Cutoff scores used for students with MD risk commonly vary between 10. and 50. percentiles (Myers et al., 2022; Nelson & Powell, 2018).

During encoding, the term "students with MD" is used when there is a classification according to ICD-10 (WHO, 2005) or DSM-5 (APA, 2013) criteria. The same terms are also used for students who have determined mathematics goals in the scope of IEP. The term "students with MD risk" is used by researchers for students who are between 10. and 50. percentiles in a standard mathematics test (Chodura et al., 2015; Möller et al., 2012). This situation might represent a heterogeneous group that also comprises students with MD. However, because of the lack of information in meta-analyses, it wasn't possible to distinguish these groups. The term "students with LD" is additionally used as there are meta-analysis studies that comprise children who have problems more than simply mathematics difficulties. Students who have been formally diagnosed with Learning Disabilities (LD), as well as those encountering impediments in their mathematical learning, fall within the classification of students with LD.

Meta-analysis Quality Level

In this study, the evaluation of the quality of the meta-analysis research is conducted using the Revised Assessment of Multiple Systematic Reviews (R-AMSTAR) scale, which was revised by Kung et al. (2010). Scores ranging, from 0 to 11 are categorized as "insufficient.", from 12 to 22 fall under the "low", from 23 to 33 are considered "medium", from 34 to 44 indicate a "high" level of quality (Young, 2017). Notably, items 8C and 8D in the R-AMSTAR scale, originally developed for clinical practice, are not utilized in this research. Instead, items 8A and 8B are combined and treated as a single score. The quality assessment process involves the first and second authors, and the average of their scores is considered the quality score. Subsequently, these quality scores are categorized according to the assessment ranges described above.

Academic performance: Mathematics success and mathematical ability of students are encoded as "mathematics performance".

Grade level: Researches are encoded as "K12", elementary and secondary according to the education levels in the studies they involve.

Bias status: Publication bias analyses of the research are analyzed and encoded as "trivial, small, and NA" (not available) according to the style they are reported in the publication. Research that does not have reports of publication bias is encoded as "NA".

Location: If the data of meta-analysis research involve various countries, they are coded as "global". If they include a single country, it is coded as "according to the country".

Report type: If the data of meta-analysis research involve only articles, they are encoded as "the article". If they include an article, a doctorate thesis, and others, they are encoded as "mixed".

Year Range: This study comprises 14 years. This is why; research is separated into two periods. The research process involves years between 2009 and 2022.

Statistical Independence

If meta-analysis researches involve more than one MD intervention program, they are encoded as “independent programs”. For instance, in their research study, Dennis, et. al. (2016) represented three different effect sizes in EI, PAI, and TBI programs. This research comprises k=27 effect size obtained from n=13 meta-analysis research.

Selection of Effect Size

Meta-analysis researchers reported effect size indexes reported k=8 effect size as Cohen d and k= 19 as Hedge’s g. Hedge’s g and Cohen d value calculation formulas are different from one another. However, Hedge’s g and Cohen's d calculations give the same value in big samplings. On the other hand, Hegde’s g value is the corrected value of Cohen d for small samplings (Marfo & Okyere, 2019; Turner & Bernard, 2006). In essence, it can be postulated that, for sufficiently large sample sizes, the effect size denoted as "g" approximates equivalence to "d." Samplings are regarded to be big enough in this research. There is a similar acceptance in different second-order (Hew et. al., 2021)

Statistical Model for Analysis

The utilization of the random-effects model is recommended when the effect sizes being analyzed in meta-analytical statistical analyses are derived from different samples or when the research studies providing the effect sizes exhibit significant variability (Borenstein et al., 2011). In this research, the random-effects model has been chosen for these specific reasons. Heterogeneity analyses of the mean effect size are conducted using the random-effects model to account for potential variability among the included studies.

Publication Bias

Reliability of the produced mean effect size is closely related to publication bias. There are many publication bias techniques in the literature (Mathur et al., 2021). In this research, publication bias analyses of the dataset incorporate several techniques, including funnel plot graphic analysis, Egger's test, and the Duval & Tweedie trim and fill analysis, as outlined by Jin et al. (2015).

Heterogeneity Analysis

Intra-group and inter-groups heterogeneity analyses are carried out according to Q statistical technique. In other words, the Q total (Qt) is calculated total heterogeneity amount while Q between (Qb) value is calculated for the between-groups heterogeneity amount. Conversely, the I^2 value is computed to assess the degree of heterogeneity among groups. (Huedo-Medina, et. al, 2006).

Results

Findings about the effect size of the dataset, total heterogeneity amount, and level are first presented in this section of the research study. Secondly, the results of the publication bias analyses are discussed. Thirdly, moderator analysis and inter-group heterogeneity analyses are presented.

Effect Size and Total Heterogeneity

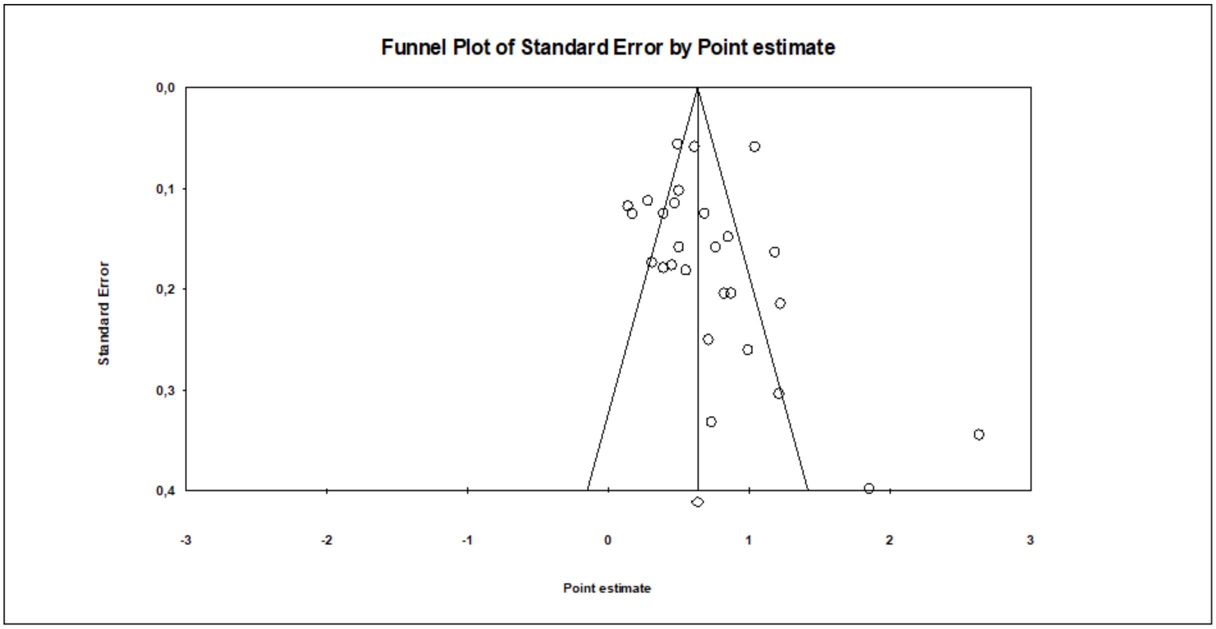
The dataset involves k=27 effect sizes independent from one another. Effect sizes vary between ES=.14 and ES=2.63. The effect of MD intervention programs on students' mathematics performance is calculated as ES=.70 LL=.56 UL=.83. In other words, the effect of MD intervention programs on students' mathematics performance is medium-level. The heterogeneity amount of the dataset is Qt=183.34 $p< .01$; the heterogeneity level is I^2=85.82. It is observed that the dataset is highly heterogeneous.

Publication Bias Analyses

Upon analyzing the Funnel Plot graphic, it becomes evident that the distribution of effect sizes in relation to the standard error is symmetrical. Figure 2 illustrates the Funnel Plot graphic of the dataset. Likewise, the results of Egger's regression test indicate that there is no statistically significant publication bias ($t = 0.92$, $p = 0.36$). Furthermore, when the Duval & Tweedie trim and fill analysis is conducted, it is determined that no additional studies need to be added ($k = 0$). In summary, based on the outcomes of the publication bias assessments and their corresponding analyses, it is reasonable to deduce that the dataset under scrutiny does not manifest discernible indications of publication bias.

Figure 2.

Funnel Plot of the Studies



Moderators and Inter-Groups Heterogeneity Analyses

The results of the moderators and inter-group heterogeneity analyses for the dataset are displayed in Table 1. The findings obtained from these analyses are summarized below.

Table 2.

Data for Moderator and Heterogeneity Analysis

Group	K	ES	LL	UL	Qb	df (Q)	p
Intervention program							
CBI	7	.74	.48	1.00			
EI	5	1.03	.71	1.35			
TBI	6	.62	.32	.92			
SBI	3	.75	.32	1.18			
VR	3	.54	.15	.92			
PAI	3	.35	-.05	.74	8.40	5	.14
Participant characteristics							
At risk MD	18	.61	.44	.78			
MD	6	1.09	.77	1.42			
LD and MD	3	.56	.15	.97	7.23	2	.03
Grade level							
Elementary	9	.75	.52	.98			
Secondary	4	.35	.01	.69			
K12	14	.76	.57	.96	4.64	2	.10
Quality							
High	21	.71	.55	.87			
Median	6	.67	.38	.95	.06	1	.81
Report							
Article	12	.69	.49	.88			
Mixed	15	.71	.52	.90	.02	1	.88
Location							
Global	22	.77	.63	.92			
USA	5	.39	.09	.68	5.41	1	.02
Year range							
2009-2015	9	.94	.70	1.17			
2016-2022	18	.58	.43	.74	6.05	1	.01

*Interventions= CBI: Cognitive Based instruction; EI: Explicit Instruction; PAI: Peer-Assisted Instruction; SBI: Schema Based Instruction; TBI: Technology Based Instruction; VR: Visual Represantation, **Difficulties= MD: Mathematics Difficulties; LD: Learning Difficulties

Statistically, it has been found that the mean effect sizes vary based on the location of the meta-analysis research (Q (1) =5.41 p=.02). Meta-analysis research in the global group (that involves different countries) produce medium-level effect size while effect sizes from the USA produce low effect size (ES=.77 LL=.63 UL=.92; ES=.39 LL=.09 UL=.68 respectively). Additionally, there is a statistically significant variation in the mean effect sizes based on the publication date of the meta-analysis research (Q (1) =6.05 p=.01). Relatively early period meta-analysis researches between 2009 and 2015 have high-level effect sizes. On the other hand, relatively current meta-analysis researches have a medium-level effect size (ES=.94 LL=.70 UL=1.17; ES=.58 LL=.43 UL=.74 respectively).

It is determined that MD intervention programs' effect on mathematics performance varies according to participant groups. In other words, mean effect sizes statistically vary according to participant groups (Q (2) =7.23 p=.03). Impact of mathematics difficulty programs in student groups with MD is determined to be high while the impact on student groups with MD risk is medium (ES=1,09 LL=.77 UL=1.47; ES=.61 LL=.44 UL=.78 respectively).

The analysis reveals that mean effect sizes do not exhibit a statistically significant variation based on the type of intervention programs (Q (5) = 8.40, p = 0.14). Nevertheless, it is worth noting that the effect size of the EI program is significantly larger than that of the other programs (ES = 1.03, LL = 0.71, UL = 1.35). Conversely, the PAI program type yields a lower effect size than the others (ES = 0.35, LL = -0.05, UL = 0.74). Stated differently, the influence of the Educational Intervention (EI) program on students' mathematical performance appears to be substantial, while the Pedagogical Approach Intervention (PAI) program demonstrates a relatively lower effect. Meanwhile, the interventions denoted as Computer-Based Instruction (CBI), Teacher-Based Instruction (TBI), Student-Based Instruction (SBI), and Virtual Reality (VR) collectively exhibit effect sizes at a moderate level.

It has been determined that the mean effect size of the meta-analysis research does not exhibit a statistically significant variation based on the school level they encompass (Q (2) =4.64 p=.10). Secondary school effect size is low (ES=.35 LL=.01 UL=.69). It is found that it produced medium-level effect size for K12 and elementary levels.

Discussion, Conclusion & Suggestions

The findings of this study offer a quantitative summary of the influence of intervention programs tailored for students with MD on their performance in mathematics. The results of this second-order meta-analysis suggest that the intervention programs designed for students with MD effectively promote their success in mathematics. According to the findings of this study, MD intervention programs have positive and medium-level effect size on students' mathematics performance (ES = .70). This result suggests that students with MD derive benefits from the implemented intervention programs.

The Effect of MD Intervention Programs on Mathematics Performance

It is found that MD programs have a medium-level effect on students' mathematics performance in general. Besides, it is determined that among the MD programs, EI has a higher impact on students' mathematics performance. On the other hand, the PAI program has a low impact on performance. The EI intervention program has significantly influenced the mathematics performance of students with MD. The outcomes of this research align with the findings of other meta-analysis studies in the literature, as Gersten et al. (2009) indicated. The results obtained suggest that explicit ınstruction serves as a significant intervention program for instructing mathematics to students with MD.

In this study, it is determined that CBI, SBI, TBI, and VR intervention programs had a high-level effect on the mathematics performance of students with MD. When the obtained result is compared to the findings in the literature, it is observed that they are in parallel (Myers et al., 2022; Myers et al., 2021). CBI intervention program helps students with MD in choosing proper strategies, articulating problem-solving processes and evaluating the solution, and using cognitive and meta-cognitive techniques during this evaluation (Iseman & Naglieri, 2011). The CBI intervention program has proven to be effective in enhancing the engagement of students with MD in the learning process and aiding in the development of problem-solving strategies, as indicated by Montague et al. (2014). Similarly, the TBI intervention program is efficient in terms of giving different opportunities such as repeating the learned information and instantly taking feedback (Kiru et al., 2018; Myers et al., 2021). Similar results are obtained in the studies that analyze the impacts of CBI and TBI intervention programs on the mathematics performance of students with MD (Myers et al., 2021). Similarly, a high level of impact is determined in previous studies about the SBI intervention program (Lein et al., 2020). However, Myers et al. (2022) calculated a slightly lower value for the SBI intervention program. Differences in statistical calculations might be the reason for this difference. Additionally, VR intervention programs contribute by attributing meaning to understanding abstract ideas and representing problems concretely at school (Gersten et al., 2009). These findings suggest that a variety of intervention programs may be viable options for the pedagogical instruction of mathematics to students afflicted with Mathematics Disability (MD). However, as students with MD are heterogeneous, it is necessary to make intervention studies that support different features of students.

The effect of PAI intervention programs on the mathematics performance of students with MD is low. Previous meta-analysis studies also support this finding (Gersten et al., 2009). It is determined that peer-supported teaching isn’t successful in MD students' training when compared to the impacts of it on other students who have typical development (Gersten et al., 2009). Mathematics education of students with MD should be carried out by experienced and knowledgeable teachers (Cortiella & Burnette, 2008; Witzel & Little, 2016). In the peer-supported teaching process, peers of the student with MD have insufficient knowledge about the education of these students. Insufficient sampling might be another reason. More studies about peer-supported education and its efficiency can be analyzed (Gersten et al., 2009).

Teachers need to be knowledgeable about efficient intervention programs to increase the success of students with MD (Myers et al., 2021). Although these intervention programs are promising in terms of having more benefits in the teaching process, it is necessary to have different types of such programs as students have different characteristics.

Investigation of Mathematics Performance According to Moderator Variables

An efficient education process is necessary to enable MD students to benefit from the general mathematics curriculum efficiently and productively (Powell et al., 2013). However, it is reported that when in-class education is not efficient, MD students need a more intense intervention (Stevenson & Reed, 2017). It is necessary to make some arrangements to present a complementary intervention to students with MD. It is determined that there is an important amount of heterogeneity in the ES among studies.

It is determined that there is important heterogeneity in the ES between research studies. This finding is in parallel with the findings of previous studies (Jitendra et al., 2020; Myers et al., 2021; Stevens et al., 2018). To determine the resource of heterogeneity, it is studied to see if the impacts of intervention programs on mathematics performance vary according to moderator variables.

Participant Characteristics

In this study, it is determined that MD intervention programs had a meaningful difference according to the features of participants. In this respect, an effect size in favor of students with MD is calculated. The group of MD students in this research study is made of individuals who only have difficulty in mathematicsThe remaining groups may present supplementary challenges encompassing issues related to reading, attention, comprehension, and writing abilities. These factors, which exert an impact on the learning process, consequently impede the mathematical achievements of students and contribute to the complexity of their responsiveness to instructional interventions. In this respect, different difficulties of students with MD can be supported (reading, attention, comprehension, and writing) and mathematics teaching can be shaped according to this dimension. In addition, in studies that developed an intervention program for students with MD, researchers don't use a standard assessment instrument to determine the mathematical difficulty (Mazzocco et al., 2013; Nelson & Powell, 2018). This situation might make it difficult to determine students that need intense academic support in math class. Furthermore, the utilization of various diagnostic methods for identifying students with MD complicates the comparison of findings across different studies on the topic, as highlighted by Nelson and Powell (2018).

Grade Level

According to the result of this second-order meta-analysis study, MD intervention programs have a lower impact on secondary school-level students. There is a medium-level impact on K12 level and elementary level students. Different ES values are calculated in the research studies focusing on the effect of education level on the mathematics performance of students with MD (Myers et al., 2022; Chodura et al., 2015; Gersten et al., 2009). The difference in the inclusion criteria might be the reason behind this difference. For instance, Myers et al. (2022) determined that intervention programs have a big effect on the primary school level. On the other hand, they reported a medium-level effect on the middle school level. Similar results are obtained in different studies on the topic (Gersten et al., 2009).

Students with MD who are at the primary school level have fewer topics to learn, and they have relatively basic-level topics. This fact increases the efficiency of interventions (Stevens et al., 2018). Students learn more complex topics as they continue their education. Researchers foresee that as the complexity of mathematics content increases in line with the grade, interventions create a more efficient development and support primary school students (Jitendra et al., 2018). When students with MD aren't supported in the mathematics learning process, they may fall behind their peers who develop normally (Nelson & Powell, 2018). This situation might make it difficult for these students to give reaction to the intervention. As mathematics is naturally volute, previous learnings are the basis of the following knowledge. Students with MD acquire their basic skills in primary school (Powell et al., 2017). When students aren't supported at an early age, interventions at the middle school level might have a low effect on their learning outcomes.

Publication Year

According to the results of this study, relatively recent meta-analysis research about MD produced a lower effect size. Further research can be carried out to see whether the results are similar or different in this regard. Seeing that the recent meta-analysis studies produced low effect size can be interpreted as a surprising result. This situation may be attributed to the inclusion of studies with larger sample sizes in recent meta-analysis studies. It is known that studies with small samplings produce higher effect size values (Gersten et al., 2009; Jitendra et al., 2018). On the other hand, it can be said that the pretest last-test randomized controlled trial studies are included in the research studies in which recent studies are analyzed. The inclusion of single-subject research studies before 2015 might have caused a high effect size. In recent meta-analyses, this tendency gave its place to experimental and quasi-experimental experimental studies. However, all these are simply some interpretations.

Location

It is determined that the impacts of meta-analysis research on MD vary according to the location they comprise. In this study, it is determined that the effect of MD intervention programs only in the USA is low. On the other hand, it is observed that global researches that comprise different countries have a higher impact. This situation might result from location bias. One of the bias problems in meta-analysis research can be location bias (Higgins & Green 2011). In their clinical practices, Vickers et al. (1998) showed that effect sizes vary according to the location of the country. A similar process can be part of the problem in practicing intervention programs.

Meta-Analysis Quality

In this study, the effect of MD intervention programs on students' mathematics performance didn't have a meaningful variation in terms of study quality. However, it can be said that the studies with higher study quality produce a higher effect size. It is expected that the studies on the impact of quality indicators on ED, studies whose study quality isn't calculated will report a lower ES (Stevens et al., 2018).

Quality indicators in special training studies are important for ensuring the support of literature to intervention programs (Cook et al., 2015). Findings should be evaluated in line with the quality of included studies (Stevens et al., 2018). Presenting the study quality might contribute to determining efficient intervention programs. The impact level of intervention programs on students with MD might differ. In this respect, quality assessments of intervention programs might allow interpretation of these programs. Calculating the quality indicators of interventions might contribute to the possibility to select efficient interventions for teaching mathematics to students with MD.

Suggestions

Three basic limitations are taken into consideration while interpreting the findings. Firstly, only 13 meta-analysis studies between the years 2009 and 2022 that analyze the impact of the mathematics intervention on the math performance of students with MD were determined. Researchers who plan to conduct future research on the subject may conduct more comprehensive second-order meta-analyses focusing on the effect of mathematics intervention on the mathematics performance of students with MD. Secondly, only the articles that use group experimental designs in their design are included in the analysis. In a variety of simple subject design research, it is determined that there are positive impacts of mathematics intervention programs on the math performance of students with MD.

Single-subject research might give information about efficient intervention programs to support the mathematical performance of students with MD. In this regard, in addition to group experimental design studies, the outcomes derived from single-subject meta-analytical investigations can be amalgamated within the framework of second-order meta-analyses. Thirdly, intervention programs that are efficient in terms of increasing the mathematics performance of students with MD are determined. It is observed that intervention programs such as EI, SBI, TBI, CBI, and VR are efficient in teaching mathematics programs. However, when the fact that students with MD have different characteristics (heterogeneous) is taken into consideration, it can be said that different types of intervention programs can also be efficient in the process of teaching mathematics.

Ethic

All procedures in this study were conducted in accordance with the ethical standards of the 1975 Declaration of Helsinki.

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