





A meta-analysis of the effect of use of materials on mathematics achievement

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Abstract

This study aimed to reveal the effect level of use of materials in educational processes on students' mathematics achievement. This study employed meta-analysis to quantitatively synthesize evidence from 75 experimental and quasi-experimental studies, providing a systematic evaluation of the effectiveness of educational materials. The results indicate that use of materials for educational purposes is an effective method for increasing students' mathematics achievement, with a statistically significant overall effect size of .48. The study yielded that as the publication year increased, the effect of material use on student achievement also increased, articles reported higher effect sizes than dissertations/theses, quasi-experimental studies yielded higher effect sizes than experimental studies, the level of effect sizes varied between different learning domains, material use had the biggest effect on student achievement in collectivist countries, and studies with interventions by researchers yielded higher effect sizes. This study offers a comprehensive meta-analytic synthesis of 75 studies on the use of educational materials in mathematics education, demonstrating that material use is an effective approach for enhancing students' mathematics achievement.

Keywords: material, mathematics achievement, meta-analysis, teaching mathematics

INTRODUCTION

As educational systems undergo a transformation, students are learning skills such as problem solving, collaboration, critical thinking, and communication that are in line with what is expected of them in the 21st century (Care et al., 2018). In addition to having mathematical knowledge, they should also be able to interpret and apply it effectively in their daily lives. A change in mathematics education is underway in this context, considering the fact that mathematics is a vital component of daily life. Education systems have also been focusing on developing students' ability to think mathematically. Due to the existence of an abstract structure, which has been expressed by many scientists, mathematics is a systematic language of science that takes place in life, thus supporting the teaching process with different applications is necessary. Mathematics education should use materials that allow for the construction of mathematical concepts more concretely and clearly, and students should be encouraged to think

like mathematicians in order to construct mathematical knowledge (Wittmann, 2021).

Materials for education, often referred to as educational or learning materials, encompass a wide range of resources used directly with learners to facilitate the acquisition of knowledge, skills, attitudes, and values. These materials can include books, audio-visual aids, charts, maps, globes, exhibit materials, and objects or phenomena that serve as focal points for educational excursions (Edenfield, 2010). Educational materials are also described as reusable curriculum components, which can include interactive simulations, multimedia materials, and web documents or sites. In accordance with the literature, instructional materials can be defined as resources and tools used to facilitate the teaching and learning process by conveying essential knowledge and skills through various media. Accordingly, based on the definitions and explanations, instructional materials can be grouped in two groups: physical (concrete materials, games, etc.) and digital (computer based, dynamic software, virtual reality, augmented reality, etc.). Instructional materials are

Contribution to the literature

- This study provides a comprehensive meta-analytic synthesis of research on the use of educational materials in mathematics education by integrating evidence from 75 experimental and quasi-experimental studies.
- It extends the existing literature by examining not only the overall effectiveness of material use on mathematics achievement but also the contextual and methodological factors associated with variation in effect sizes.
- It offers comparative evidence across different educational contexts and implementation conditions, thereby informing future research and instructional practice in mathematics education.

designed to enhance the teaching/learning process by providing procedural or factual guidance, ensuring that all learners have access to complete and accurate information, and facilitating self-directed and self-paced learning (Campbell, 1999).

In the information age we live in, teaching approaches also vary with the development of technology. Today, the dynamic elements in the abstract structure of mathematics can be made more visible with the help of different technologies. In this context, studies related to dynamic software (Natsiopoulos & Angelakeris, 2023), virtual reality (Moyer-Packenham & Westenskow, 2013; Shin et al., 2023), and augmented reality (Syafri et al., 2021) are also available. Teaching materials are used in teaching environments to embody abstract concepts and to perform teaching more effectively. In addition, these materials provide students with the opportunity to work freely and provide research-based environments. It is possible to use materials to appeal to more than one sense, and teachers can use them as teaching tools when teaching certain mathematical concepts to students (Moyer, 2001). In this context, the use of materials allows students to develop a deeper understanding and understanding of mathematical thinking, to establish complex conceptual connections, and to be problem solvers.

Research on the use of instructional materials in mathematics education has produced a substantial body of empirical studies as well as several evidence syntheses. However, existing syntheses have generally focused on specific types of materials or particular learner groups rather than examining physical and digital materials together. Earlier meta-analyses, for example, addressed computer technology (Li & Ma, 2010), dynamic geometry software (Chan & Leung, 2014), infographics (Elaldı & Çifçi, 2021), concrete manipulatives (Carbonneau et al., 2013), and manipulative-based interventions for students at risk or identified with disabilities (Peltier et al., 2020). In addition, Kul et al. (2018) synthesized 54 experimental studies conducted in Türkiye and reported that the use of instructional materials had a positive and high effect on mathematics achievement. More recent review studies likewise indicate that research on mathematics materials has expanded rapidly across both digital and

physical forms, yet the literature remains fragmented by tool type, participant group, and research context (Drijvers & Sinclair, 2024; Ochugboju & Díez-Palomar, 2025). Accordingly, the literature still appears to lack an up-to-date meta-analysis that jointly examines physical and digital materials within a broader evidence base and tests moderator variables that may explain differences in effect sizes across studies.

Addressing this gap is important because the effectiveness of instructional materials may vary not only by material type but also by contextual and cultural conditions. In particular, cultural orientation may shape classroom interaction, collaboration, and students' help-seeking and help-giving behaviors, which in turn may influence how learners engage with instructional materials (Jeng, 2024; Ouyang et al., 2025). Therefore, examining individualism-collectivism as a moderator may provide a more nuanced understanding of when and under what conditions instructional materials support mathematics achievement. Meta-analysis is well suited to this purpose because it enables the statistical synthesis of findings from independent studies and allows both overall and moderator effects to be examined systematically (Borenstein et al., 2009). In this respect, the present study aims to provide updated quantitative evidence on the effects of both physical and digital materials on mathematics achievement and to identify the moderator variables associated with these effects.

Hence the aim of this study is to reveal the effect level of use of materials in educational processes on students' mathematics achievement and to determine whether the variables of type, year, design, and content area of the study; education level and country of the participants; type of the material used and practitioner are meaningful moderators on the effect size. Considering all these study results, the current study is expected to contribute to the literature by aiming to test the following hypotheses:

- H₁.** Use of materials in educational processes has a positive effect on students' mathematics achievement.
- H₂.** Year of the publication is a moderator for the positive effect of use of materials on student achievement.

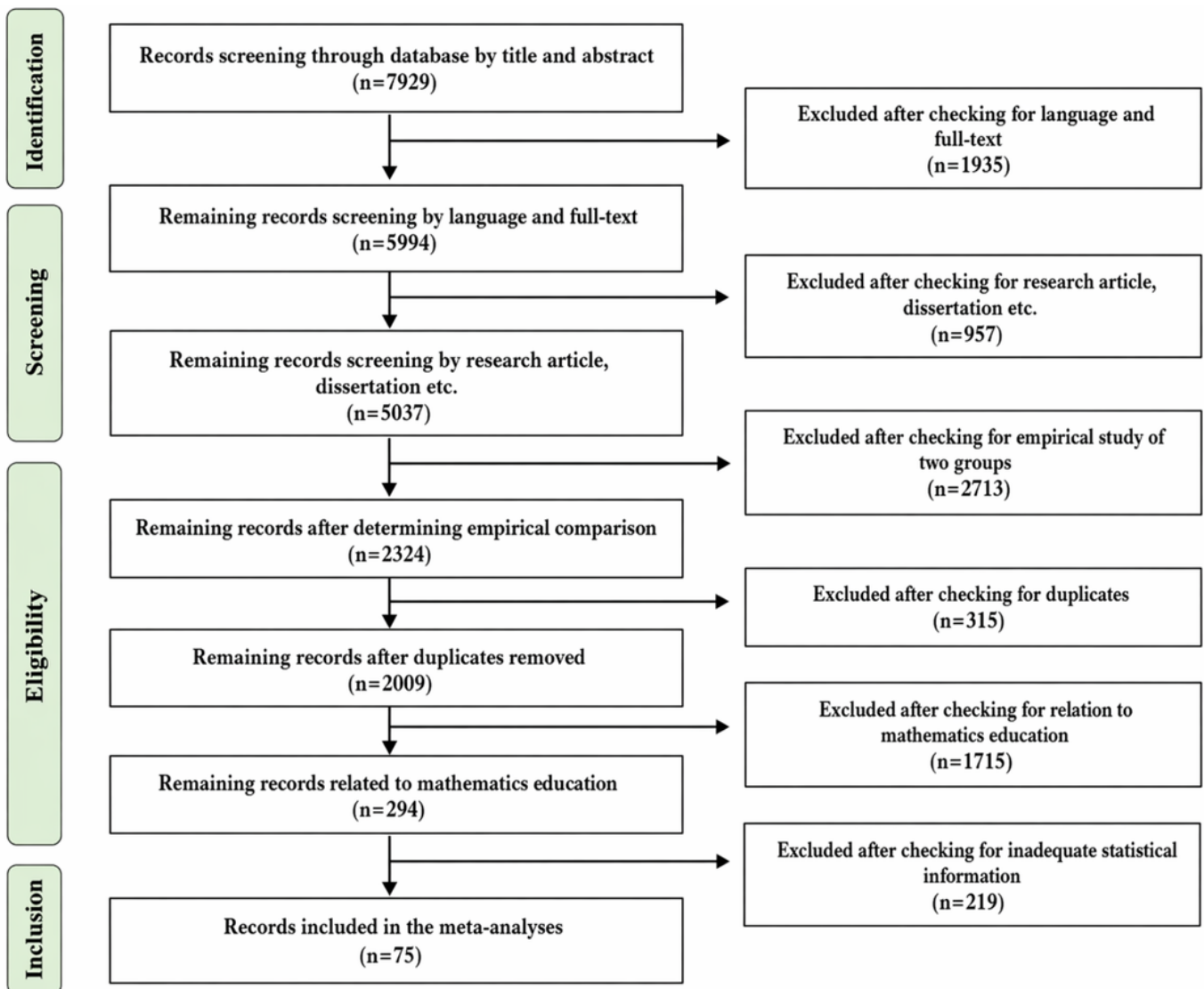


Figure 1. Literature search, screening and selection process (Source: Authors' own elaboration)

- H₃. Type of the publication is a moderator for the positive effect of use of materials on student achievement.
- H₄. Design of the study is a moderator for the positive effect of use of materials on student achievement.
- H₅. Mathematical content area of the study is a moderator for the positive effect of use of materials on student achievement.
- H₆. Educational level of the participants is a moderator for the positive effect of use of materials on student achievement.
- H₇. Country of the participants is a moderator for the positive effect of use of materials on student achievement.
- H₈. Type of the material used is a moderator for the positive effect of use of materials on student achievement.
- H₉. Practitioner is a moderator for the positive effect of use of materials on student achievement.

METHOD

Research Design

The effect of use of materials on student achievement was tested with a meta-analysis design. Meta-analysis is a design used to gather the results of several independent research studies on certain subjects and to apply a statistical analysis on the findings acquired (Borenstein et al., 2009; Wampold et al., 2000). Meta-analysis has been used as a statistical approach for pooling data from related experimental studies with the aim of this study.

Search and Selection Process

Meta-analysis pools studies related to the aim of the researcher in an aggregate data with an effect measure of the outcome variable. Hence, a flowchart has been created to picture out the screening of the studies to be included in the analysis. Figure 1 shows the numbers of the studies examined across the phases.

Table 1. Inclusion criteria

Criteria	Inclusion criteria
Time period	2024 December and earlier
Language	English
Publication type	Peer-reviewed journal articles, book chapter, book, thesis, dissertation (full-text)
Research design	Experimental or quasi-experimental design with control group
Relevance	Mathematics education
Results of research	Adequate quantitative data for calculating the effect size or reporting the effect size
Educational outcomes	Mathematics achievement

First, in the screening phase, the titles and abstracts of the articles identified through the keyword search were reviewed, and a pre-selection process was carried out. The data sources selected for the study were the ScienceDirect, ProQuest, EBSCOhost, and Web of Science academic databases. The search strategy was based on three groups of keywords: material-related descriptors, performance-related descriptors, and mathematics-related descriptors. The material-related descriptors were “materyal, manipulative, material, virtual, concrete, equipment, 3D, and augmented”, the performance-related descriptors were “başarı, performans, achievement, success, and performance”, and the mathematics-related descriptors were “matematik, mathematics, and mathematical”. In Web of Science, EBSCOhost, and ProQuest, material-related descriptors were searched in the title field, whereas performance- and mathematics-related descriptors were searched in the abstract field. In Web of Science, for example, the search string was formulated as follows: TI = (materyal OR manipulative OR material OR virtual OR concrete OR equipment OR 3D OR augmented) AND AB = (başarı OR performans OR achievement OR success OR performance) AND AB = (matematik OR mathematics OR mathematical). In ScienceDirect, performance- and mathematics-related descriptors were searched in the title, abstract, or keyword fields, while material-related descriptors were searched in the title field. In the second stage, the full texts of the pre-selected studies were examined, and studies that did not report sufficient statistical values or did not include an experimental and a control group were excluded.

Selection Criteria

Studies included in this meta-analysis were required to be written in English and available in full text. There was no restriction on publication year. **Table 1** presents the inclusion criteria used for the studies identified through the database search.

As shown in **Table 1**, the inclusion criteria were established to ensure the methodological rigor and relevance of the studies included in the meta-analysis. Eligible publication types included peer-reviewed journal articles, book chapters, books, master’s theses, and doctoral dissertations. In addition, the studies were required to focus on mathematics education, employ an experimental or quasi-experimental design with a

control group, and report sufficient quantitative data to calculate or directly provide effect sizes. Finally, only studies examining mathematics achievement as an educational outcome were included in the analysis. Although book chapters and books were considered eligible during the screening process, no studies of these types met all inclusion criteria and were therefore not included in the final sample.

Final Selection and Data Extraction

A meta-analysis coding form in Microsoft Excel developed by the researchers in accordance with the research hypotheses has been used as a data collection tool. Instructional materials can include printed forms such as textbooks, workbooks, and supplementary materials, as well as digital formats like computer software, DVDs, CD-ROMs, online services, and other electronic media. Accordingly, based on the definitions and explanations, this study adopted a dual classification for instructional materials which are grouped as physical (concrete materials, games, etc.) and digital (computer based, dynamic software, virtual reality, augmented reality, etc.).

The information below was included in the coding form:

- information about the study (reference, the publication type and year, the type of experimental design, content area of mathematics, educational level and country of the participants, the material type used, the practitioner) and
- statistics from the study (sampling size, post-test means and standard deviation for both of the experiment and control groups).

Countries were classified as collectivist or individualist based on their predominant cultural orientation as reported in the relevant literature. To ensure the reliability of the coding process, all studies included in the meta-analysis were coded independently by three researchers using a predefined coding form. After the independent coding was completed, the coding results were compared and reviewed together with a fourth researcher. Any discrepancies were discussed and resolved through consensus, and the final coding dataset was created accordingly. Intercoder reliability was assessed based on the initial independent coding, and the percentage agreement among coders was found

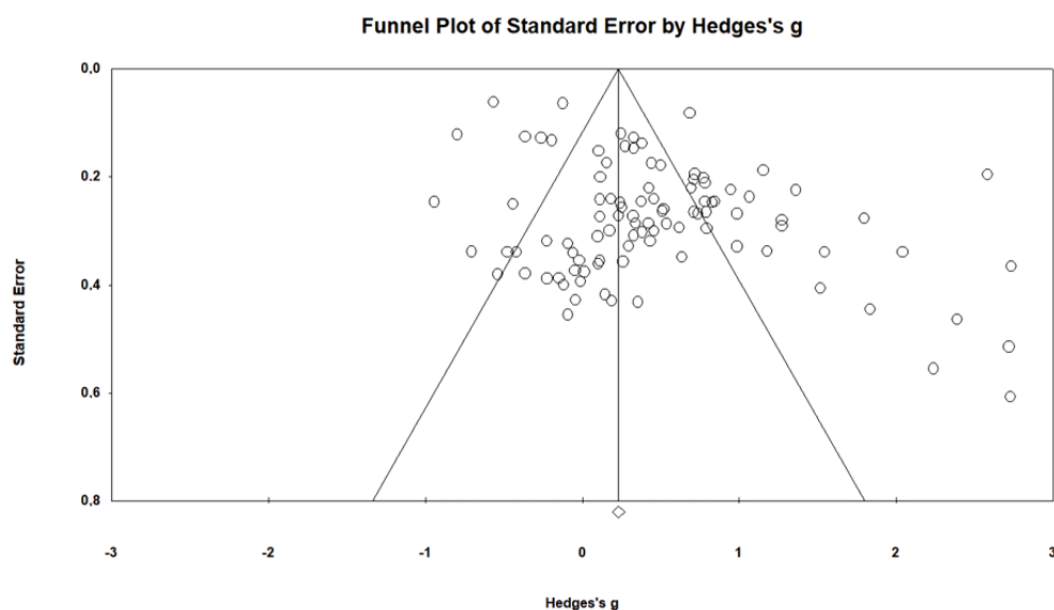


Figure 2. Funnel plot of the effect sizes (Source: Authors' own elaboration)

to be 86%, indicating an acceptable level of coding consistency. A total of 75 eligible publications (theses, dissertations, and research articles) were included in the final meta-analysis study, which were listed in **Appendix A**. Although some publications contributed more than one effect size, these effect sizes were derived from independent samples/subsamples and were therefore treated as statistically independent units in the analysis. Hence, the search and screening through the publications led to the identification of 98 independent effect sizes. The pooled sample size was 10,344.

Data Analysis

Hedges' g statistic is used to measure the effect size for the difference between means (Borenstein et al., 2009). The current study used this statistic to present the effect sizes of the studies. A funnel plot, and trim-and-fill method were used to identify potential publication bias. The trim-and-fill method is a nonparametric technique used to adjust for publication bias in meta-analyses. A meta-analysis with random effect model is more accurate when effects sizes of studies included in it are different from one another, according to Borenstein et al. (2009). As a result, the Cochran Q -test and I^2 test were used to assess statistical heterogeneity. As a result of the Cochran- Q test, p values below .05 indicate heterogeneity within the sample. Hence, a random effect model was used for the meta-analysis processes within the study. Moderators, which could be people or situations, temper or modulate the magnitude of the effect of an independent variable on a dependent variable. Accordingly, moderator analysis was conducted in order to identify the source of heterogeneity in the effect sizes among the studies. *Comprehensive meta-analysis* software was used to analyze the data. Furthermore, eight moderator

variables that were expected to have a role in the average effect size were identified in the study. These moderators include publication type and year, the type of experimental design, content area of mathematics, educational level and country of the participants, the material type used, and the practitioner. The statistical significance of the difference between moderator variables is tested using the Q statistic method developed by Hedges and Olkin (1985). Q -between (Q_b) values were used within the study to determine the statistical significance of the differences as it tests the homogeneity between the groups (Borenstein et al., 2009).

FINDINGS

Initially, findings regarding publication bias were reported. This is followed by the heterogeneity of the distribution of effect sizes and the findings concerning the moderator analysis.

Publication Bias

As Borenstein et al. (2009) proposed, funnel plot, and trim-fill method were examined together whether effect size estimates were symmetrical based on standard errors. The publication bias of the included research studies has been determined using funnel plots in the first place. **Figure 2** illustrates how publication bias affected the research studies included in the meta-analysis based on a funnel plot.

The funnel plot presented in **Figure 2** indicates that the distribution of effect sizes is not fully symmetrical. Notably, studies with smaller sample sizes tend to report larger effect sizes, especially in the lower right quadrant of the plot. The funnel plot appeared not to be perfectly symmetrical; however, this visual impression alone does

Table 2. Duval and Tweedie’s (2000) trim-and-fill test results

	Studies trimmed	Point estimate	Confidence interval		Q
			Lower limit	Upper limit	
Observed values		.48	.34	.61	982.81
Adjusted values	0	.48	.34	.61	982.81

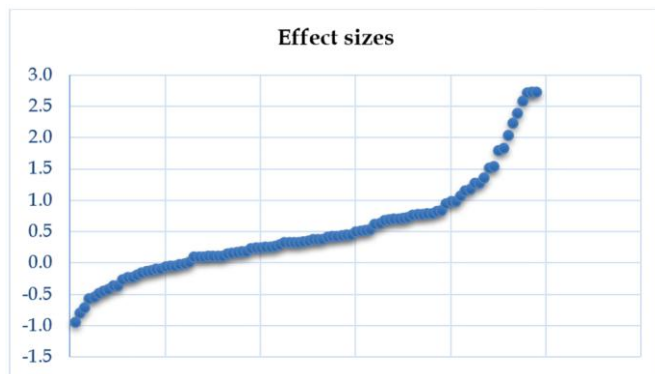


Figure 3. The distribution of the effect sizes (Source: Authors’ own elaboration)

not constitute strong evidence of publication bias. In addition to examining the biasness in publications through the funnel plot, the results of Duval and Tweedie’s (2000) trim and fill test, which was applied to determine the effect of biasness in publications, have also been examined. **Table 2** presents the results of this test.

As is seen in **Table 2**, there is no difference between the observed and adjusted effect sizes created to fix the effect of the biasness of publications. Duval and Tweedie (2000) trim-and-fill method estimated an effect size of $k = 0$ that would be added to the left side of the mean to achieve a more balanced, symmetrical distribution. Hence, the trim-and-fill procedure estimated no missing studies and produced no change in the pooled effect size.

The Overall Impact of Mobile Learning on Academic Achievement

After testing the publication bias of the studies, a total of 98 effect sizes have been analyzed through meta-analysis. **Figure 3** shows the distribution of the effect sizes of the studies included.

As is seen in **Figure 3**, the results of the meta-analysis revealed that the effect sizes of the studies ranged from -0.94 and 2.73. Moreover, the majority of the effect sizes (76%) were in favor of experimental groups which were exposed to the use of materials. An examination of the effect sizes showed that 54% of them were statistically significant, while the remaining of them were not. Forest

plot showing the visual representation of the amount of variation between the effect size of each study and an estimate of the overall effect sizes of all studies has been presented in the **Appendix B. Table 3** shows the results of meta-analysis for the effect of use of materials in educational processes on students’ mathematics achievement.

Table 3 indicates that the significance of the Q-statistic ($Q = 982.81, p < .001$) provides evidence for heterogeneity. This heterogeneous distribution of the effect sizes is also supported by I^2 value (90.13) as it is bigger than 75% (Borenstein et al., 2009). Accordingly, the results of the random effect model should be taken into consideration. The findings supported H_1 which states that use of materials in educational processes has a positive effect on students’ mathematics achievement. The effect size of use of materials on student achievement was calculated to be .48. This value shows that use of materials has a medium level effect on students’ mathematics achievement.

Findings Regarding Moderator Analysis

Moderator analysis have been carried out to uncover the reasons behind heterogeneous distribution. The moderator variables used within the study were as follows: publication type and year, the type of experimental design, content area of mathematics, educational level and country of the participants, the material type used, and the practitioner. Sub-group analysis results across the moderators have been presented in **Table 4**.

The results of the moderator analysis supported the hypothesis H_2 , which asserts the moderator role of the publication year. The moderator analysis showed that the difference between the levels of effect of publication year was statistically significant ($Q_b = 13.88, p < .01$). While these effect size values were positive and significant for the years 2001-2011 ($p < .05$) and 2012-2024 ($p < .01$), it is not significant for the years 2000 and earlier ($p > .05$). This result shows that the effect of material use on student achievement has increased in recent years. The results of the homogeneity test showed that there was a significant difference between the calculated effect

Table 3. Overall effect sizes

	N	ES	SE	Variance	95% confidence interval		z	p	Test of heterogeneity in effect size			I^2
					Lower	Upper			Q	df(Q)	p	
Fixed	98	.23**	.02	.00	.19	.27	11.13	.00	982.81	97	.00	90.13
Random	98	.48**	.07	.01	.34	.61	6.85	.00				

Note. ** $p < .01$

Table 4. Examination of effects through moderator analysis

Moderators	k	ES	SE	%95 CI
Publication year	98	$Q_b = 13.88^{**}, df = 2$		
.....-2000	30	.16	.09	[-0.01-0.34]
2001-2011	13	.30*	.14	[0.02-0.58]
2012-2024	55	.71**	.12	[0.48-0.94]
Publication type	98	$Q_b = 19.24^{**}, df = 1$		
Dissertation	50	.19*	.07	[0.06-0.33]
Article	48	.78**	.11	[0.56-1.00]
Design	98	$Q_b = 4.25^*, df = 1$		
Experimental	62	.35**	.07	[0.22-0.48]
Quasi-experimental	36	.71**	.16	[0.39-1.02]
Content area	98	$Q_b = 17.76^{**}, df = 4$		
Algebra	25	.70**	.15	[0.40-0.99]
Data-probability	2	.02	.22	[-0.40-0.45]
Geometry	23	.75**	.14	[0.47-1.03]
Numbers	22	.37*	.14	[0.08-0.65]
Mixed	26	.16	.11	[-0.05-0.37]
School level	98	$Q_b = 7.20, df = 4$		
Pre-school	3	.66	.67	[-0.66-1.97]
Primary school	23	.79**	.15	[0.50-1.08]
Middle school	32	.29*	.14	[0.01-0.55]
High school	23	.49**	.11	[0.28-0.69]
University	17	.37**	.13	[0.11-0.64]
Country	98	$Q_b = 12.38^{**}, df = 1$		
Collectivist	30	.83**	.13	[0.58-1.09]
Individualist	68	.31**	.07	[0.16-0.45]
Material type	98	$Q_b = 2.83, df = 2$		
Physical	45	.37**	.10	[0.17-0.56]
Digital	47	.61**	.11	[0.39-0.83]
Both	6	.39**	.15	[0.11-0.68]
Practitioner	98	$Q_b = 7.10^*, df = 2$		
Teacher	52	.30**	.08	[0.13-0.47]
Researcher	41	.63**	.11	[0.43-0.84]
Both	5	.06	.57	[-0.50-2.17]

Note. CI: Confidence interval; * $p < .05$; & ** $p < .01$

size values of studies according to publication type ($Q_b = 19.24, p < .01$), which supports the hypothesis **H3**. These effect size values were positive and significant for dissertations/theses and articles ($p < .01$). Furthermore, the effect size difference between the designs of the studies was statistically significant ($Q_b = 4.25, p < .05$), which supports the hypothesis **H4**. These effect size values were positive and significant for experimental and quasi-experimental studies ($p < .01$).

The difference in effect sizes between the content area categories was also statistically significant ($Q_b = 17.76, p < .05$), which supports the hypothesis **H5**. While these effect size values were positive and significant for algebra ($p < .01$), geometry ($p < .01$), and numbers ($p < .05$); it is not significant for data/probability ($p > .05$) and mixed areas ($p > .05$). This finding suggests that the level of the effect sizes changes across different learning domains and that geometry and algebra had the highest level of effect sizes. Additionally, the difference in effect sizes between the countries of the participants was found to be statistically significant ($Q_b = 12.38, p < .05$),

which supports the hypothesis **H7**. The effect size values for both of the collectivist and individualist countries were significant ($p < .01$). Moreover, effect size difference between the practitioners was also found to be statistically significant ($Q_b = 7.10, p < .05$), which supports the hypothesis **H9**. The effect size values for practitioners as teacher and researcher were significant ($p < .01$).

In the moderator analysis, the effect size difference between the school levels ($Q_b = 7.20, p > .05$), and material types used within the studies ($Q_b = 2.83, p > .05$) were not found to be statistically significant, which means rejecting the hypotheses **H6**, and **H8**. However, the effect size values for primary school ($p < .01$), middle school ($p < .05$), high school ($p < .01$), and university ($p < .01$) were found to be positive and significant. Similarly, the effect size values for the use of physical ($p < .01$), digital ($p < .01$), and both physical and digital ($p < .01$) materials were positive and significant.

DISCUSSION

A total of 75 studies yielding 98 effect sizes were included in this meta-analysis, which was designed to examine the magnitude of the effect size of use of materials in mathematics education process on students' mathematics achievement. The results of this meta-analysis revealed that use of materials has a medium level positive effect on students' mathematics achievement, a finding that is consistent with research showing that material-supported and multi-representational mathematics instruction can improve students' comprehension, retention, and overall achievement when compared with more conventional forms of teaching (Milenković et al., 2025; Mpuangnan et al., 2024). Accordingly, Moyer-Packenham and Westenskow (2013) found that digital manipulatives were moderately effective on student achievement in their meta-analysis study. In this context, it is understood that the result of the relevant study coincides with the result obtained from this study. On the other hand, Kul et al. (2018) determined that the use of materials was highly effective on academic achievement. In addition to all these, Kablan (2016) revealed that the effect of manipulative use on the academic success of students with different learning styles is different. Learning environment was also effective in this difference. Therefore, the differences in the learning environment of the researches and the learning styles of the sample group can be shown as another reason for these different results in the literature.

The moderator analysis carried out in regard to the year of publication showed that the level of effect of use of materials on student achievement was statistically significant across categories of publication years. The effect sizes of the studies published between 2012 and 2024 have the highest values and have significantly

differed from the previous years' effect sizes. A meta-analysis by Domino (2010) found that manipulative use had a positive impact on mathematics achievement regardless of the year of publication. As he examined the studies published before 2010, it can be deduced that the rapid progress in technology effects education, and the increase in the number of technology-supported materials increases the effect of material use on students' academic achievement. Furthermore, publication type has also a moderator role for the effect of use of materials on student achievement. The findings suggest that articles report higher effect sizes than dissertations or theses. While this result is consistent with the results of studies in the literature (e.g., Domino, 2010; Li & Ma, 2010), the results of Kul et al. (2018) does not coincide with the current study results. On the other hand, Li and Ma (2010) determined that unpublished studies had a larger effect size than the theses. The results of this meta-analysis indicate that study design served as a significant moderator of the overall effect, with quasi-experimental studies yielding larger positive effects compared to other designs. This finding is consistent with existing literature, which suggests that quasi-experimental designs tend to produce higher estimated effect sizes due to the nature of their methodological constraints (Shadish et al., 2002). In many cases, the absence of random assignment in quasi-experimental studies may lead to less stringent control of extraneous variables, potentially inflating observed effects (Cook & Campbell, 1979).

Statistically significant results were found through the moderator variable analysis regarding content areas of mathematics. The effect sizes found for the geometry and algebra were the highest among effect sizes of all content areas. Similarly, Kul et al. (2018) determined that geometry and measurement had a larger effect size than other mathematics fields. It is noteworthy that the effect size appeared to be higher in geometry and algebra, two domains in which students often benefit from concrete, visual, and multiple representations that make conceptual relationships more accessible. Consistent with this pattern, studies indicate that physical manipulatives can improve achievement in geometry, while multiple representations and digital supports can strengthen conceptual understanding and achievement in algebra (Elbir & Özmen, 2024; Mensah et al., 2025; Milenković et al., 2025; Mpuangnan et al., 2024). Researchers have emphasized that the reason for this may be due to the effect of augmented reality applications in concretizing subjects such as geometry, algebra, statistics and probability, especially for students at this level.

The moderator analysis conducted with respect to school level indicated that the effects of using instructional materials on students' mathematics achievement did not vary significantly across the different school level sub-categories. In other words,

regardless of the school level, the observed effects remained relatively consistent. This finding suggests that instructional materials may have a broadly applicable role in supporting mathematics learning, independent of the specific school level. Similar results have been reported in prior meta-analyses, indicating that the effectiveness of instructional materials in mathematics is influenced more by how the materials are implemented and aligned with learning objectives rather than by the students' developmental or school-level characteristics (Cheung & Slavin, 2013; Hattie, 2009). In this regard, instructional materials and technology-enhanced instructional designs that incorporate active participation, adaptive scaffolding, and timely feedback appear to be beneficial across elementary, secondary, and higher education contexts, with reported gains in vocabulary acquisition, student engagement, knowledge retention, and academic achievement (Cubacub & Jimenez, 2025; Ghaemi & Bahrami, 2025; Osei et al., 2025; Yıldırım & Turgut, 2025). This finding is consistent with the finding of the study conducted by Kul et al. (2018).

A further moderator variable considered in this analysis was the countries of the participants. The variable of country played a moderator role for the effect of use of materials on students' mathematics achievement. This result indicates that use of materials has the biggest effect on student achievement in collectivist countries. Collectivism is about societies in which people integrate into strong and interconnected groups and continue to protect them in exchange for unquestioning loyalty throughout their lives, unlike individualism, where the ties between individuals are weak and individualism is at the forefront (Hofstede et al., 2005). From an educational perspective, it may be more accurate to argue that group-based learning can be brought to the fore in mathematics instruction when material use is embedded in well-structured collaborative activities. Accordingly, the use of materials in mathematics teaching may be more effective for improving academic achievement when it is organized through carefully facilitated group work, since collaborative learning has been associated with higher mathematics achievement and motivation, and material- or manipulative-supported instruction has been shown to strengthen mathematical learning; however, these benefits depend on instructional design, group formation, group size, and the prevention of social loafing rather than on broad cultural assumptions alone (Akendita et al., 2026; Dereje, 2023; Milenković et al., 2025; Tosuntaş, 2020).

Moderator analysis results suggest that there were not significant differences across the sub-categories of material types used in the studies. The result obtained for the material type moderator is in line with the meta-analysis results of Kablan et al. (2013). However, Kul et al. (2018) revealed that the type of material has a moderately positive effect on academic achievement.

According to the result of the related research, physical and digital materials have a greater effect on mathematics achievement. Similarly, Gullion (2024) concluded in his study that physical manipulatives are more effective than the mixed use of manipulatives, and that the manipulative with the least impact is digital manipulatives. It is thought that one of the important factors in obtaining these different results in the literature stems from the level of the sample group examined in the research.

The results of the moderator analyses indicated that the person implementing the intervention (i.e., the practitioner) also influenced the effectiveness of using instructional materials on students' mathematics achievement. Notably, studies in which the researcher acted as the implementer demonstrated larger effect sizes than those where the intervention was administered by the classroom teacher. This finding is consistent with prior meta-analytic evidence suggesting that researcher-led interventions tend to yield higher effects due to greater fidelity of implementation, closer alignment with theoretical frameworks, and the researcher's direct investment in achieving positive outcomes (Cheung & Slavin, 2016; Stipek et al., 1998). At the same time, this result highlights a potential limitation for the generalizability and scalability of interventions. When researchers implement treatments, the conditions often differ from those of typical classrooms, making it challenging to replicate the same level of effectiveness when implemented by regular teachers. Peltier et al. (2020) also found that the effect of material use on mathematics achievement increased depending on the quality of the practitioners. Based on this result, the researchers emphasized that the effect of teachers can be increased through training.

Implications

This research shows that all materials, whether physical or digital, have a positive impact on students' academic achievement, and especially that this impact increases with each passing year. In addition, according to the current research, the use of materials increases the academic achievement of students in more abstract contents of mathematics such as geometry and algebra. Considering that primary school students are in the concrete operational period according to Piaget, and that the mathematical contents at high school and undergraduate levels are more abstract, it can be deduced from the research results that the use of materials play an important role, especially in concretizing abstract subjects. It can also be deduced that the use of different types of materials together will further increase students' academic achievement in mathematics. In this sense, teachers can benefit from this rich resource pool and should also be supported in developing their own physical and digital materials. One of the important results of the research is that the use of

materials increases academic achievement more in collectivist countries. Based on this result, it can be inferred that the use of materials in group studies that encourage collaborative learning, which is also underlined by the constructivist approach, will be more effective in increasing academic achievement. A limitation of the study is that effect sizes were calculated from post-test scores only. Because the meta-analysis included quasi-experimental studies, this strategy may have introduced bias where baseline differences existed between groups. Although this decision was necessary due to inconsistent reporting of pre-test data across studies, the results should be interpreted cautiously. Future research may benefit from using pre-/post-test effect size calculations when such data are available.

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APPENDIX A

Table A1. References of meta-analysis studies

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APPENDIX B: FOREST PLOT

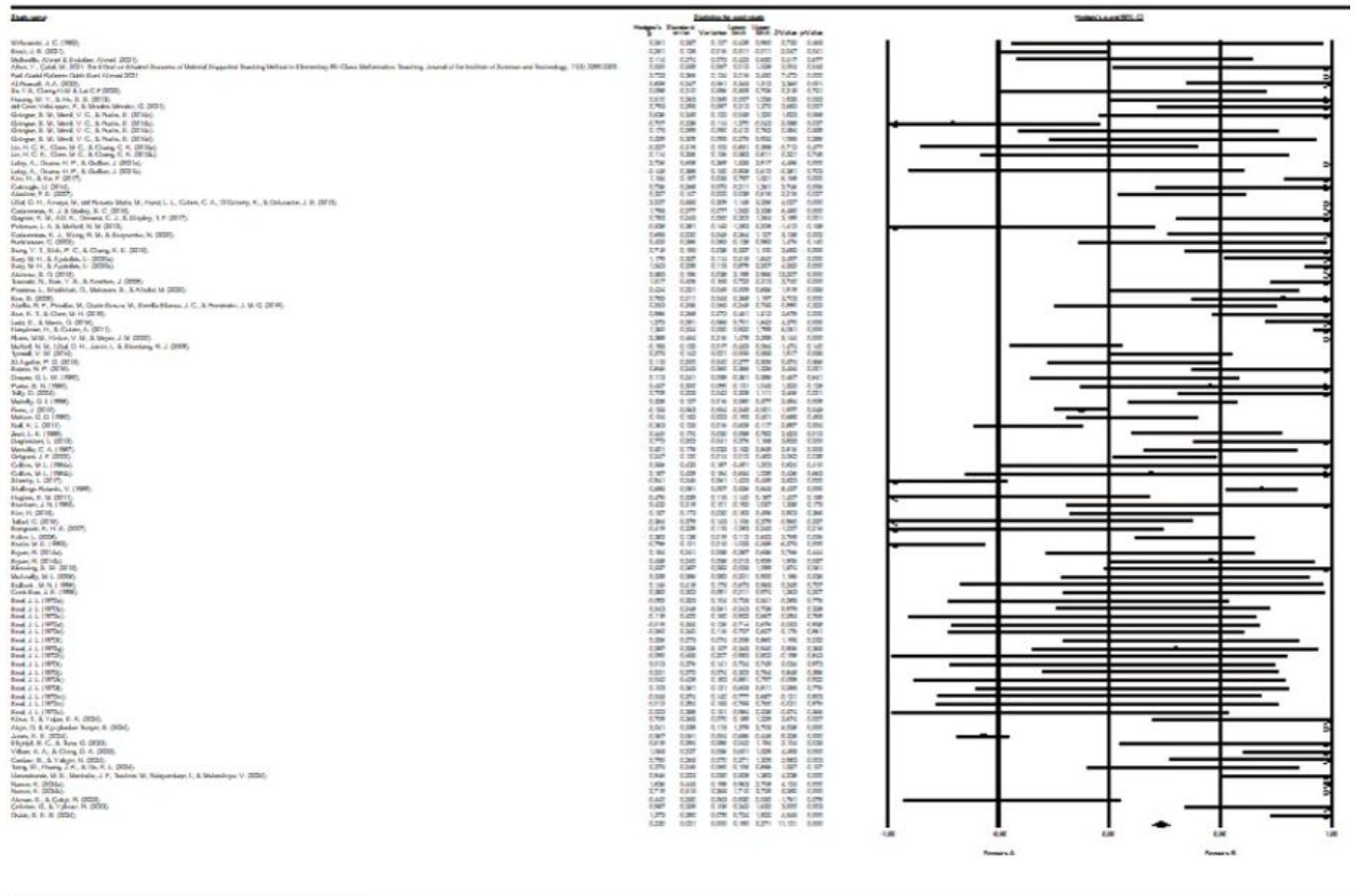


Figure B1. Forest plot diagram (Source: Authors' own elaboration)

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