



Conceptual Change Texts and Students' Learning Outcomes: A Meta-Analysis of Experimental Studies

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ABSTRACT:

Conceptual change texts (CCTs) are widely used in science education to address students' misconceptions and promote meaningful learning. However, findings across individual studies vary, and the magnitude and consistency of their effects remain unclear. This meta-analysis synthesized 28 studies to examine the effectiveness of CCT-based interventions in improving learning outcomes compared with conventional or alternative instructional approaches. A random-effects model was used, with Hedges' g as the standardized effect-size measure. Heterogeneity, prediction intervals, moderator effects, and funnel-plot asymmetry were also examined. The results showed a statistically significant positive overall effect of CCTs on learning outcomes, $g = 0.98$, $SE = 0.24$, 95% CI [0.49, 1.47], $t(27) = 4.08$, $p < .001$. Substantial between-study heterogeneity was observed, $Q(27) = 275.66$, $p < .001$, $I^2 = 95.63\%$, and $\tau^2 = 1.35$. The 95% prediction interval ranged from -1.45 to 3.41 , indicating considerable variation in effects across future contexts. Meta-regression showed that study year and research design were not significant moderators, whereas country was significant, $F(4, 6) = 4.41$, $p = .05$. Funnel-plot and asymmetry tests indicated potential small-study effects. The findings indicate that CCTs can improve learning outcomes, although their effects vary substantially across contexts. Science teachers should use CCTs as part of learner-centred conceptual change instruction, beginning with elicitation of students' prior conceptions and explicitly addressing discrepancies between alternative and scientific explanations.

KEYWORDS: conceptual change texts, conceptual change, science education, misconceptions, meta-analysis, Hedges' g , learning outcomes

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1.0 INTRODUCTION

Students enter science classrooms with ideas about natural phenomena developed through everyday experiences, prior learning, language, social interactions, and observations. Some of these ideas differ from scientifically accepted explanations and may persist despite formal instruction. Such alternative conceptions can influence how students interpret new information and construct scientific knowledge, making students' prior conceptions an important consideration in science teaching and learning (Duit & Treagust, 2003; Taber, 2019). Addressing these conceptions is therefore a central concern in science education (Taber, 2019). Conceptual change provides an important framework for addressing students' alternative conceptions. From this perspective, meaningful learning may require learners to reconsider existing explanations and reorganize their knowledge when those explanations fail to account for new evidence or phenomena (Posner et al., 1982). Conceptual change approaches therefore seek to engage learners' existing ideas rather than simply transmit scientifically accepted information.

These approaches include conceptual change texts (CCTs), refutation texts, cognitive conflict strategies, concept mapping, bridging approaches, and other interventions designed to challenge and reconstruct alternative conceptions (Pacaci et al., 2024). CCTs are an important text-based approach because they explicitly address learners' existing conceptions and introduce scientifically

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accepted explanations. Closely related refutation texts identify alternative or incorrect conceptions, refute them, and provide scientifically consistent explanations. Both approaches recognize that presenting correct information alone may not be sufficient to replace well-established misconceptions. A review of two decades of research found that refutation texts were more likely than traditional expository texts to facilitate conceptual change (Tippett, 2010). Palmer (2003) similarly demonstrated the relevance of refutational texts to restructuring learners' conceptual knowledge.

For the present meta-analysis, CCTs and refutation texts are treated as related text-based conceptual change interventions because both explicitly engage learners' existing conceptions and provide scientifically accepted alternatives. Research has examined these approaches across diverse science topics and educational levels. In chemistry, CCT-based instruction has been used to improve understanding of cellular respiration (Çakir et al., 2002), energy in chemical reactions (Taştan et al., 2008), chemical bonding (Özmen et al., 2009), reaction rates (Çalik et al., 2010; Kingir & Geban, 2012), alkenes (Sendur & Toprak, 2013), electrochemistry (Önder, 2017), and chemical equilibrium (Özmen & Naseriazar, 2018). In biology, studies have addressed ecology and cellular respiration (Al Khawaldeh & Al Olaimat, 2010; Gulcan et al., 2015). Other research has examined heat and temperature, astronomy, symmetry, and broader science learning outcomes (Batdal Karaduman, 2019; Işcan & Seyhan, 2021; Şensoy & Yeşil, 2025; Yürük & Eroğlu, 2016).

The interventions have also been combined with other instructional approaches. CCTs have been integrated with animations (Özmen et al., 2009), concept mapping (Al Khawaldeh & Al Olaimat, 2010), simulations (Özmen & Naseriazar, 2018), metaconceptual activities (Batdal Karaduman, 2019; Yürük & Eroğlu, 2016), the REACT strategy (Ültay et al., 2015), and the 5E learning model (Işcan & Seyhan, 2021). Research has further extended to preservice teachers and other teacher populations (Dersch et al., 2022; Götzfried et al., 2024; Şensoy & Yeşil, 2025). The outcomes examined also extend beyond misconception correction. Studies have investigated conceptual understanding, academic achievement, scientific process skills, attitudes toward science, and other learning outcomes. Emre and Kayabas (2020), for example, examined academic achievement, scientific process skills, attitudes toward science, and misconceptions among fourth-grade students. Çaycı (2018) investigated conceptual change text-based teaching across several educational variables, while Sel and Sözer (2019) examined students' conceptual understanding.

Research has similarly examined personalized refutation texts and combinations with other learning activities (Dersch et al., 2022; Prinz et al., 2021; Will et al., 2019). Recent studies have also investigated personalized refutation texts among teachers (Dersch et al., 2026a) and stories and digital stories incorporating refutation texts (Korur et al., 2025). Despite this growing evidence, findings from individual studies may vary because of differences in participants, subject matter, intervention duration, implementation, comparison conditions, and measurement instruments.

Meta-analysis provides a systematic approach for integrating such findings and estimating a pooled effect while accounting for sampling error and between-study variability. Armağan et al. (2017) examined CCTs and reported a large pooled effect on students' achievement, but their synthesis included studies only up to 2010. Schroeder and Kucera (2022) conducted a meta-analysis of between-subjects experiments and reported a positive effect of refutation texts on learning. Pacaci et al. (2024) synthesized 218 primary studies examining cognitive conflict, cognitive bridging, and ontological category shift as conceptual change strategies and reported a large pooled effect using a random-effects model.

However, evidence concerning text-based conceptual change interventions remains distributed across different terminology, research designs, science topics, populations, and outcome measures. Moreover, substantial research has emerged since the periods covered by earlier syntheses. The present meta-analysis therefore integrates experimental evidence on CCTs and refutation texts to estimate their pooled effect on students' learning outcomes.

2.0 THEORETICAL FRAMEWORK

This meta-analysis is theoretically grounded in the conceptual change theory of Posner et al. (1982), complemented by contemporary research that has expanded understanding of how learners revise and reorganise their existing conceptions. Conceptual change is particularly important in science education because learners enter formal instruction with prior ideas developed through everyday experiences, informal learning, and previous instruction. These ideas may differ from scientifically accepted explanations and can persist even after learners have been exposed to formal instruction. Contemporary research continues to conceptualise conceptual change as a process involving the revision, restructuring, or reorganisation of existing knowledge rather than the simple acquisition of new information (Aleknavičiūtė et al., 2023; Amiruddin et al., 2025).

Posner et al. (1982) proposed that conceptual change is facilitated when learners become dissatisfied with their existing conception and encounter an alternative conception that is intelligible, plausible, and fruitful. Dissatisfaction occurs when an existing conception is unable to adequately explain an observation, phenomenon, or problem. The learner must then understand the alternative conception, perceive it as consistent with available evidence, and recognise its usefulness for explaining new phenomena or solving problems. These conditions provide a theoretical foundation for instructional approaches designed to challenge alternative conceptions and facilitate the construction of scientifically accepted explanations.

The theoretical assumptions of Posner et al. (1982) are particularly relevant to conceptual change texts (CCTs) and refutational texts. Such texts commonly identify a misconception or alternative conception, explicitly refute the conception using

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evidence or explanation, and present a scientifically accepted explanation. Recent synthesis research confirms that refutational texts constitute an important category of conceptual change intervention.

Aleknavičiūtė et al. (2023), in a review and meta-analysis of 30 years of conceptual change research in biology, found that refutational text was the most frequently used intervention type and reported substantial effects of conceptual change interventions on conceptual understanding. Pacaci et al. (2024) found significant effects for several conceptual change approaches, including cognitive conflict, cognitive bridging, and ontological category shift. Their findings demonstrate that conceptual change interventions are not theoretically or instructionally homogeneous. Different approaches may engage different mechanisms for challenging and restructuring learners' existing conceptions. Götzfried et al. (2024) examined conceptual change among pre-service teachers using conceptual change texts and podcasts. Their findings indicated that conceptual change conditions produced greater reductions in misconceptions than expository conditions, both immediately after the intervention and at follow-up.

Dorsah and Yaayin (2019) examined the effect of conceptual change texts (CCTs) on students' misconceptions in electrochemistry. They reported a significant difference in the percentage of misconceptions after the intervention, indicating greater conceptual change among students exposed to CCTs. The findings suggest that the conceptual change approach, such as the use of text-based materials, can serve as a useful medium for supporting conceptual restructuring.

Amiruddin et al. (2025), in a systematic review of conceptual change research, identified continuing interest in how cognitive and contextual factors influence conceptual restructuring and highlighted the need for improved assessment approaches, adaptive instructional strategies, and further investigation of the long-term effects of conceptual change interventions. These theoretical and empirical perspectives provide a rationale for examining the effectiveness of text-based conceptual change interventions across different studies and educational contexts. CCTs are expected to promote learning by making alternative conceptions explicit, creating conditions for dissatisfaction with inadequate explanations, and presenting scientifically acceptable conceptions that are intelligible, plausible, and fruitful. However, the literature also suggests that the effectiveness of these interventions may depend on learners' prior knowledge, the characteristics of the intervention, the outcome measure, the instructional context, and the nature of the conceptual difficulty being addressed (Aleknavičiūtė et al., 2023; Pacaci et al., 2024).

2.1 Conceptual Framework

Conceptual Change Texts (CCTs) are specialized instructional materials designed to facilitate changes in learners' existing conceptions. They explicitly address alternative conceptions and present scientifically accepted explanations. CCTs are based on the view that learners enter instructional situations with prior knowledge and explanatory frameworks that influence how they interpret new information. When these conceptions conflict with scientific explanations, simply presenting correct information may not produce meaningful conceptual change. CCTs therefore engage learners' existing ideas and encourage them to examine and reorganize their understanding (Posner et al., 1982; Palmer, 2003; Liljedahl, 2011). The theoretical foundation of CCTs is rooted in the conceptual change framework of Posner et al. (1982). This framework proposes that conceptual change involves restructuring existing knowledge when learners encounter a conception that provides a more satisfactory explanation of a phenomenon. Posner et al. identified four conditions that support accommodation: dissatisfaction with the existing conception, intelligibility, plausibility, and fruitfulness of the new conception. CCTs translate these principles into instructional materials by highlighting limitations in existing conceptions and presenting scientific alternatives that learners can understand, evaluate, and apply (Posner et al., 1982; Liljedahl, 2011).

A CCT is therefore a purposefully structured text that activates an alternative conception, highlights its limitations, and provides a scientifically accepted explanation (Palmer, 2003; Naeem Sarwar et al., 2024). Unlike conventional expository texts, which primarily communicate scientific information, CCTs are organized around conceptual difficulties that learners may experience. They may begin by presenting a common alternative conception, asking learners to predict an outcome, or describing an explanation that reflects their existing thinking. Evidence, questions, or situations can then be introduced to reveal limitations in that conception and encourage consideration of a scientific alternative (Posner et al., 1982; Naeem Sarwar et al., 2024).

The new conception must not only challenge the existing one but also satisfy the conditions proposed by Posner et al. (1982). Intelligibility refers to the learner's ability to understand the meaning of the new conception and the relationships among its components. Plausibility concerns whether the learner considers the conception reasonable and consistent with available evidence or accepted knowledge. Fruitfulness refers to its capacity to explain phenomena, solve problems, and support further learning (Posner et al., 1982; Palmer, 2003).

These conditions help explain why conceptual change requires more than exposure to scientifically correct information. Although CCTs vary in structure and content, they generally follow a common instructional sequence. They activate an existing conception, establish a discrepancy between that conception and scientific evidence, and introduce a scientifically accepted alternative. This sequence distinguishes CCTs from ordinary science texts because it is deliberately designed to support conceptual restructuring (Palmer, 2003; Naeem Sarwar et al., 2024). Liljedahl (2011) emphasizes that conceptual change involves modifying existing conceptions rather than simply adding new information. CCTs reflect this view by explicitly connecting learners' existing ideas with scientific explanations.

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CCTs are also consistent with constructivist perspectives, which emphasize that learners actively construct meaning from prior knowledge and experience. From this perspective, alternative conceptions may function as coherent explanatory frameworks rather than isolated pieces of incorrect information. Consequently, they can be resistant to change. Naeem Sarwar et al. (2024) describe CCTs as a constructivist approach for addressing such conceptions. Conceptual change is therefore an active and complex cognitive process rather than a guaranteed outcome of instruction. Gennen (2023) notes that different theoretical perspectives explain how learners' existing knowledge structures may change. CCTs should consequently be viewed as instructional mechanisms that create conditions conducive to conceptual change rather than procedures that automatically produce it.

The effectiveness of CCTs depends partly on how effectively they connect with learners' existing conceptions. If the relevant conception is not activated, learners may process the scientific explanation without recognizing its relationship to their prior understanding. Similarly, challenging an alternative conception without providing an intelligible and plausible replacement may leave learners aware of a problem without developing an adequate explanation. Effective CCTs therefore need to both expose limitations in existing conceptions and provide scientifically meaningful alternatives (Posner et al., 1982).

2.2 Empirical Review

Meta-analytic research provides a quantitative basis for evaluating the effectiveness of conceptual change and text-based interventions by synthesizing findings across studies conducted in different subject areas, educational levels, samples, and instructional contexts. Unlike individual studies, meta-analyses provide pooled estimates of effects and allow researchers to examine the consistency and variability of findings across the accumulated evidence. One of the earliest meta-analyses specifically examining conceptual change texts (CCTs) was conducted by Armağan et al. (2010). The study synthesized 42 published and unpublished studies conducted between 1995 and 2010 and examined 42 experimental groups. The overall effect size was $g = 1.16$, indicating a large positive effect of CCTs on students' academic achievement. Armağan et al. (2010) also examined whether the effects varied according to study characteristics, including publication status, assessment instrument, study origin, subject matter, type of instruction, school level, sample size, publication date, and treatment duration. Most of these variables did not produce statistically significant differences, although instructor effect was significant.

The evidence was subsequently extended through research on refutation texts, which share with CCTs the goal of explicitly addressing learners' alternative conceptions. Schroeder and Kucera (2022) conducted a random-effects meta-analysis of 33 studies comprising 44 independent comparisons. They reported a positive moderate effect of refutation texts on learning, $g = 0.41$, 95% CI [0.30, 0.51], compared with other learning conditions. The analysis also revealed significant heterogeneity, $Q(43) = 109.59$, $p < .001$, $I^2 = 60.76\%$. Schroeder and Kucera (2022) further reported that the effect was consistent across a range of contexts, including content domains, assessment types, and assessment timing, and found no substantial evidence that publication bias explained the overall effect.

Pacaci et al. (2024) broadened the evidence base by conducting a comprehensive meta-analysis of conceptual change strategies in science education. Their synthesis included 218 primary studies and examined three categories of strategies: cognitive conflict, cognitive bridging, and ontological category shift. Using a random-effects model, they reported a large overall effect, $g = 1.10$, 95% CI [1.01, 1.19], $p < .001$. The strategy-specific effects were also positive: cognitive conflict, $g = 1.10$; cognitive bridging, $g = 1.06$; and ontological category shift, $g = 0.88$. However, the prediction interval ranged from 0.19 to 2.38, indicating substantial variability in effects across studies. Their final meta-regression model explained approximately 35% of the observed heterogeneity. The findings of Pacaci et al. (2024) provide broad evidence for the effectiveness of conceptual change-oriented instruction while also demonstrating that its effects vary across instructional and study characteristics. These meta-analyses indicate that conceptual change-oriented interventions can improve science learning, but they also reveal substantial variation in effect sizes across studies.

3.0 METHODOLOGY

3.1 Research Design

This study employed a systematic review and meta-analysis of experimental studies. Meta-analysis provides a quantitative procedure for combining effect estimates from multiple empirical studies addressing a common research question, thereby providing a more precise estimate of the underlying effect than can generally be obtained from individual studies (Borenstein, 2009; Cheung & Vijayakumar, 2016; Field & Gillett, 2010). The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The methodological procedures followed the major stages of meta-analysis, including formulation of the review question, development of eligibility criteria, systematic identification and selection of studies, extraction and coding of relevant information, calculation of effect sizes, statistical synthesis, assessment of heterogeneity, and evaluation of potential publication bias (Field & Gillett, 2010; Hansen et al., 2022).

3.2 Eligibility and Selection Criteria

Explicit eligibility criteria were established before the final selection of studies (Ahn & Kang, 2018; Cheung & Vijayakumar, 2016; Field & Gillett, 2010). Studies were included when they satisfied all of the following criteria:

Table 1: Eligibility requirements

<i>Criterion</i>	<i>Eligibility Requirements</i>
Intervention	Studies examined a text-based conceptual change intervention identified by the authors as a conceptual change text; refutation text, conceptual change text instruction, or a sufficiently similar text-based intervention explicitly designed to identify, challenge, and reconstruct students' alternative conceptions.
Research design	Studies employed an experimental or quasi-experimental design involving an intervention group and a comparison or control group and provided sufficient quantitative information to calculate a standardized effect size.
Participants	Studies involved learners at the primary, secondary, or tertiary level, including pre-service or in-service teachers.
Outcome	Studies reported quantitative measures of learning outcomes directly associated with the intervention, including academic achievement, conceptual understanding, conceptual knowledge, misconception reduction, or other measures reflecting changes in students' learning.
Comparison condition	The intervention was compared with conventional, traditional, or alternative instruction, or another clearly identifiable comparison condition.
Statistical information	Studies reported sufficient statistical information to calculate a standardized effect size, including group means, standard deviations, and sample sizes, or convertible statistics such as <i>t</i> , <i>F</i> , or other relevant test statistics.
Publication type	Peer-reviewed journal articles and conference papers were eligible for inclusion.
Language and accessibility	Studies published in English and available in sufficient detail to permit screening, coding, data extraction, and interpretation were eligible for inclusion.

Studies were excluded when they (a) were theoretical, conceptual, or narrative papers without empirical data; (b) were literature reviews or previous meta-analyses; (c) investigated conceptual change interventions without a text-based component; (d) did not include an appropriate comparison condition; (e) did not report a learning outcome; (f) lacked sufficient statistical information for effect-size calculation; or (g) were duplicate reports of the same study.

3.3 Search Strategy and Sources

A systematic literature search was conducted to identify empirical studies examining the effects of Conceptual Change Texts (CCTs) and refutation texts on students' learning outcomes. The search was conducted across major electronic databases, including Taylor & Francis Online, SpringerLink, Wiley Online Library, SAGE Publications, Education Resources Information Center (ERIC), ProQuest, EBSCOhost, and Web of Science. The databases were searched using combinations of keywords relating to the intervention, participants, and learning outcomes. The search terms included "conceptual change text," "conceptual change texts," "conceptual change instruction," "refutation text," "refutation instruction," "refutational text," "misconception," "alternative conception," "conceptual understanding," "achievement," and "learning outcomes." Boolean operators AND and OR were used to combine the search terms. The search and selection procedures were documented to enhance transparency and reproducibility (Ahn & Kang, 2018; Cheung & Vijayakumar, 2016; Hansen et al., 2022; Page et al., 2021).

3.4 Screening and Selection

The study selection process followed the PRISMA 2020 guidelines. A total of 56 records were identified through the database search. After removing nine duplicate records, 47 records remained for title and abstract screening. At this stage, five records were excluded because they did not meet the preliminary eligibility criteria. The remaining 42 reports were sought for retrieval, and all 42 reports were successfully retrieved. These reports were subsequently assessed against the predetermined inclusion and exclusion criteria.

During the eligibility assessment, 14 reports were excluded for specific reasons. Three reports were excluded because they did not provide sufficient statistical information to calculate a standardized effect size, six were review or meta-analytic studies rather than primary empirical studies, and five examined interventions that were not text-based conceptual change interventions. Following the full-text eligibility assessment, 28 studies met all the inclusion criteria and were included in the meta-analysis. Thus, the final sample comprised 28 eligible primary studies ($k = 28$) that provided sufficient quantitative evidence for calculating Hedges' g and synthesizing the effects of text-based conceptual change interventions on students' learning outcomes. The screening process was documented using a PRISMA 2020 flow diagram (Page et al., 2021) as shown in Figure 1.

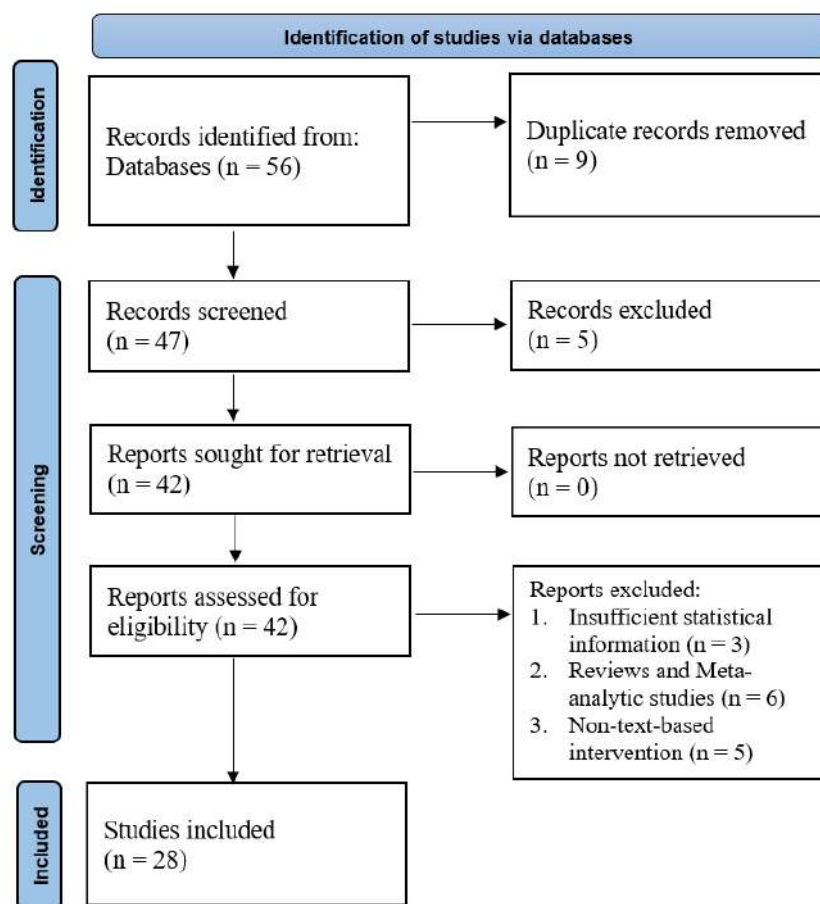


Figure 1: PRISMA flow diagram of the selection process

3.5 Data Extraction and Coding

A structured data-extraction and coding form was developed to ensure systematic and consistent collection of information from all eligible studies (Hansen et al., 2022). For each study, information was extracted on the author(s) and year of publication, study title, country or geographical location, educational level, subject area, study design, and characteristics of the participants. Information on sample size was recorded separately for the intervention and comparison groups. The coding process also captured the outcome measures used to assess students' learning, together with the means and standard deviations for the intervention and comparison groups. Information concerning the intervention and comparison conditions was recorded to facilitate interpretation of differences across studies. Finally, effect sizes and effect size standard errors required to calculate Hedges' g and its sampling variance were computed from the reported results.

3.6 Effect-Size Calculation

Hedges' g was selected as the principal effect-size metric because the included studies used different instruments and scales to assess learning outcomes. Standardized effect sizes allow outcomes measured using different instruments to be synthesized on a common metric. For studies reporting the means, standard deviations, and sample sizes of intervention and comparison groups, the standardized mean difference was calculated. Hedges' g was used because it provides a small-sample correction to the standardized mean difference and therefore reduces potential bias in studies with relatively small samples (Borenstein, 2009; Field & Gillett, 2010). Positive effect sizes indicated higher learning outcomes for students receiving text-based conceptual change interventions relative to the comparison condition.

3.7 Meta-Analytic Model

A random-effects meta-analysis was conducted to estimate the overall effect of text-based conceptual change interventions. The random-effects model was selected because the included studies differed in potentially important characteristics, including participants, educational levels, subject areas, intervention characteristics, instructional duration, outcome measures, and comparison conditions. Therefore, the true intervention effect was not assumed to be identical across studies. The random-effects model accounts for both within-study sampling error and between-study variation in the underlying true effects (Borenstein, 2009; Cheung & Vijayakumar, 2016; Hansen et al., 2022). The principal outcome was the pooled Hedges' g , accompanied by its standard error, 95% confidence interval, significance test, and 95% prediction interval.

3.8 Assessment of Heterogeneity

Between-study heterogeneity was assessed using Cochran's Q statistic, I^2 , and the estimated between-study variance (τ^2) and standard deviation (τ). Cochran's Q was used to test whether the observed variability among effect sizes exceeded that expected from sampling error alone. The I^2 statistic was used to quantify the proportion of total variability attributable to differences between studies rather than sampling error. The τ^2 and τ estimates provided measures of the magnitude of between-study variation on the effect-size scale. In addition, the 95% prediction interval was examined to assess the extent to which intervention effects might vary across comparable future studies. Heterogeneity statistics were interpreted alongside substantive differences among the included studies rather than solely according to conventional numerical thresholds (Borenstein, 2009; Cheung & Vijayakumar, 2016; Hansen et al., 2022).

3.9 Moderator Analysis

Random-effects meta-regression was conducted to investigate whether selected study characteristics were associated with variation in effect sizes. Study year, country, and research design were examined as categorical moderators. Overall moderator effects were evaluated using F tests with the Knapp-Hartung adjustment, which provides a more conservative assessment of uncertainty in meta-regression models, particularly when the number of studies is limited. Where an overall moderator effect was statistically significant, the corresponding coefficient estimates, standard errors, 95% confidence intervals, and t -tests were examined to identify statistically significant contrasts between moderator categories. The moderator analyses were interpreted as associations with variation in effect sizes rather than as evidence of causal effects.

3.10 Assessment of Small-Study Effects

Potential small-study effects were examined using a funnel plot of Hedges' g against the standard error of each study's effect estimate. Visual inspection of the funnel plot was complemented by statistical tests of funnel-plot asymmetry. The results of the asymmetry tests were interpreted cautiously because funnel-plot asymmetry may arise from several sources, including small-study effects, differences in methodological characteristics, outcome measures, intervention conditions, or genuine between-study heterogeneity. Consequently, statistical evidence of asymmetry was not interpreted as definitive evidence of publication bias, particularly in the presence of substantial heterogeneity.

3.11 Data Analysis

The extracted information was organized into a structured dataset containing study characteristics, sample sizes for intervention and comparison groups, intervention and comparison conditions, outcome measures, and statistical information required to calculate effect sizes, including group means, standard deviations, and, where means and standard deviations were unavailable, other relevant statistics such as t , F , p , and correlation coefficients. The meta-analysis was conducted using JASP, Version 0.98.1 (JASP Team, 2026). The software was used to calculate Hedges' g , standard errors, pooled random-effects estimates, 95% confidence intervals, heterogeneity statistics, τ^2 and τ , prediction intervals, moderator meta-regression models, and funnel-plot asymmetry diagnostics. The moderator analyses incorporated the Knapp-Hartung adjustment. All statistical tests were evaluated using a conventional significance level of $\alpha = .05$.

3.12 Reporting of the Review

The systematic review and meta-analysis were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). The report presents the study-selection process, characteristics of the included studies, individual effect-size estimates, pooled random-effects estimate, 95% confidence interval, 95% prediction interval, heterogeneity statistics, moderator analyses, and assessment of funnel-plot asymmetry. The reporting structure was designed to provide transparent information about both the overall effectiveness of text-based conceptual change interventions and the extent to which their effects varied across studies and study characteristics.

4.0 RESULTS

4.1 Characteristics of the Studies

A total of 28 studies ($k = 28$) were included in the meta-analysis. The studies examined the pooled effects of text-based conceptual change interventions, including conceptual change texts (CCTs) and refutation-oriented texts, on students' learning outcomes. The studies were published between 2002 and 2025 and were conducted across five countries: Turkey, Germany, the United States, Jordan, and Pakistan.

4.1.1 Geographical Distribution

The evidence base was concentrated in Turkey, which accounted for 20 of the 28 studies ($k = 20$, 71.4%). These studies examined conceptual change or refutation-oriented interventions across chemistry, biology, physics, science education, mathematics, social studies, and astronomy. Examples include Çakir et al. (2002), Çalik et al. (2010), Sendur and Toprak (2013), Batdal Karaduman (2019), Emre and Kayabaş (2020), Taşlıdere (2021), and Yürük and Eroğlu (2016). Germany contributed three studies ($k = 3$, 10.7%), including Dersch et al. (2022), Götzfried et al. (2024), and Prinz et al. (2021). Similarly, the United States contributed three studies ($k = 3$, 10.7%), including Hunsu et al. (2023), Peltier et al. (2020), and Will et al. (2019). Jordan and Pakistan each

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contributed one study ($k = 1$, 3.6%), represented by Al Khawaldeh and Al Olaimat (2010) and Naeem Sarwar et al. (2024), respectively.

4.1.2 Subject Areas and Topics

The 28 studies covered a broad range of disciplines. Chemistry was the largest category, with eight studies ($k = 8$, 28.6%). The chemistry topics included reaction rates, chemical bonding, chemical equilibrium, electrochemistry, alkenes, solutions, and energy in chemical reactions (Çalik et al., 2010; Kingir & Geban, 2012; Önder, 2017; Özmen et al., 2009; Özmen & Naseriazar, 2018; Sendur & Toprak, 2013; Taştan et al., 2008; Ültay et al., 2015). Biology accounted for four studies ($k = 4$, 14.3%), covering cellular respiration, ecology, and genetics (Al Khawaldeh & Al Olaimat, 2010; Çakir et al., 2002; Gulcan et al., 2015; Hunsu et al., 2023). Science education was represented by three studies ($k = 3$, 10.7%), whereas general science and physics each accounted for two studies ($k = 2$, 7.1%). The physics studies focused on pressure, buoyancy, and mechanical waves (Özkan & Selçuk, 2015; Taşlıdere, 2021). Educational psychology also accounted for two studies ($k = 2$, 7.1%), represented by Dersch et al. (2022) and Götzfried et al. (2024).

The remaining studies addressed mathematics, nanoscience and nanotechnology, statistics, social studies, astronomy, dyslexia education, and other conceptual topics. For example, Batdal Karaduman (2019) examined symmetry in mathematics, Prinz et al. (2021) investigated misconceptions concerning covariance, Peltier et al. (2020) addressed misconceptions about dyslexia, and Götzfried et al. (2024) examined the learning-styles myth. Overall, the disciplinary distribution indicates that text-based conceptual change interventions have been applied across diverse subject areas, extending beyond traditional science-related misconceptions.

4.1.3 Educational Levels and Participants

The studies involved participants from four educational levels. Undergraduate students constituted the largest group, appearing in 15 studies ($k = 15$, 53.6%). These studies included preservice teachers and university students from science, mathematics, statistics, chemistry, astronomy, and related disciplines (Batdal Karaduman, 2019; Hunsu et al., 2023; Naeem Sarwar et al., 2024; Peltier et al., 2020; Prinz et al., 2021; Sendur & Toprak, 2013; Şensoy & Yeşil Asana, 2025; Taşlıdere, 2021; Ültay et al., 2015; Will et al., 2019; Yumuşak et al., 2015; Yürük & Eroğlu, 2016).

Secondary-school students were represented in nine studies ($k = 9$, 32.1%). These participants were mainly in Grades 9 to 11 and studied biology, chemistry, physics, or general science (Al Khawaldeh & Al Olaimat, 2010; Çakir et al., 2002; Çalik et al., 2010; Gulcan et al., 2015; Kingir & Geban, 2012; Önder, 2017; Özkan & Selçuk, 2015; Özmen et al., 2009; Taştan et al., 2008). Primary-school pupils were represented in three studies ($k = 3$, 10.7%), including Emre and Kayabaş (2020), Işcan and Seyhan (2021), and Sel and Sözer (2019). In-service teachers were represented in one study ($k = 1$, 3.6%), Dersch et al. (2022).

4.1.4 Research Designs

quasi-experimental designs were the most common, appearing in 18 studies ($k = 18$, 64.3%). These studies generally employed pretest-posttest comparisons using intact or non-equivalent groups. Examples include Al Khawaldeh and Al Olaimat (2010), Çalik et al. (2010), Emre and Kayabaş (2020), Gulcan et al. (2015), Işcan and Seyhan (2021), Özmen et al. (2009), Özmen and Naseriazar (2018), Sendur and Toprak (2013), and Taşlıdere (2021). Randomized experimental designs were used in five studies ($k = 5$, 17.9%), including Çakir et al. (2002), Dersch et al. (2022), Götzfried et al. (2024), Hunsu et al. (2023), and Prinz et al. (2021). Experimental pretest-posttest designs without explicit randomization were employed in four studies ($k = 4$, 14.3%), represented by Batdal Karaduman (2019), Çaycı (2018), Peltier et al. (2020), and Yürük and Eroğlu (2016). Finally, one study ($k = 1$, 3.6%), Will et al. (2019), employed a within-subject experimental design.

4.1.5 Intervention and Comparison Conditions

The interventions included CCTs, refutation texts, and closely related text-based approaches. Some were implemented as stand-alone texts, whereas others incorporated additional instructional components. Eight studies ($k = 8$, 28.6%) combined text-based interventions with concept mapping, metaconceptual activities, computer animations, simulations, concept cartoons, or computer-assisted instruction (Al Khawaldeh & Al Olaimat, 2010; Batdal Karaduman, 2019; Naeem Sarwar et al., 2024; Özmen et al., 2009; Özmen & Naseriazar, 2018; Taşlıdere, 2021; Yumuşak et al., 2015; Yürük & Eroğlu, 2016). For example, Al Khawaldeh and Al Olaimat (2010) combined CCTs with concept mapping, whereas Özmen et al. (2009) incorporated computer animations.

Conventional instruction was used as the comparison condition in approximately half of the studies. Other comparison conditions included expository or classical texts, context-based learning, and alternative active-learning approaches. For example, Sendur and Toprak (2013) compared CCTs with traditional teaching, whereas Şensoy and Yeşil Asana (2025) compared CCTs, classical texts, and traditional learning conditions.

4.1.6 Publication Period

The studies spanned 24 years, from 2002 to 2025. The earliest study was Çakir et al. (2002), which examined CCT-oriented instruction in cellular respiration among Grade 11 students in Turkey. The most recent studies were published in 2024 and 2025. These included Götzfried et al. (2024), which examined conceptual change concerning the learning-styles myth among pre-service teachers in Germany; Naeem Sarwar et al. (2024), which investigated CCTs combined with concept mapping in nanoscience education in Pakistan; and Şensoy and Yeşil Asana (2025), which examined CCTs in astronomy education.

4.2 Publication Bias

A funnel plot was constructed to assess potential small-study effects and funnel-plot asymmetry among the 28 studies. The plot showed Hedges' g against the standard error, with power contours ranging from 30% to 100%. Most studies were concentrated around small to moderate positive effect sizes, approximately 0 to 2, with standard errors generally between 0.2 and 0.3. A smaller number of studies reported larger positive effects above 4 and standard errors exceeding 0.5, indicating lower precision. Visual inspection suggested some asymmetry, with a greater concentration of positive effect estimates. Studies with smaller standard errors were mainly located in higher-power regions, whereas studies with larger standard errors were more frequently located in lower-power regions. This pattern indicates variation in study precision and statistical power. Figure 2 presents the Funnel plot of the studies.

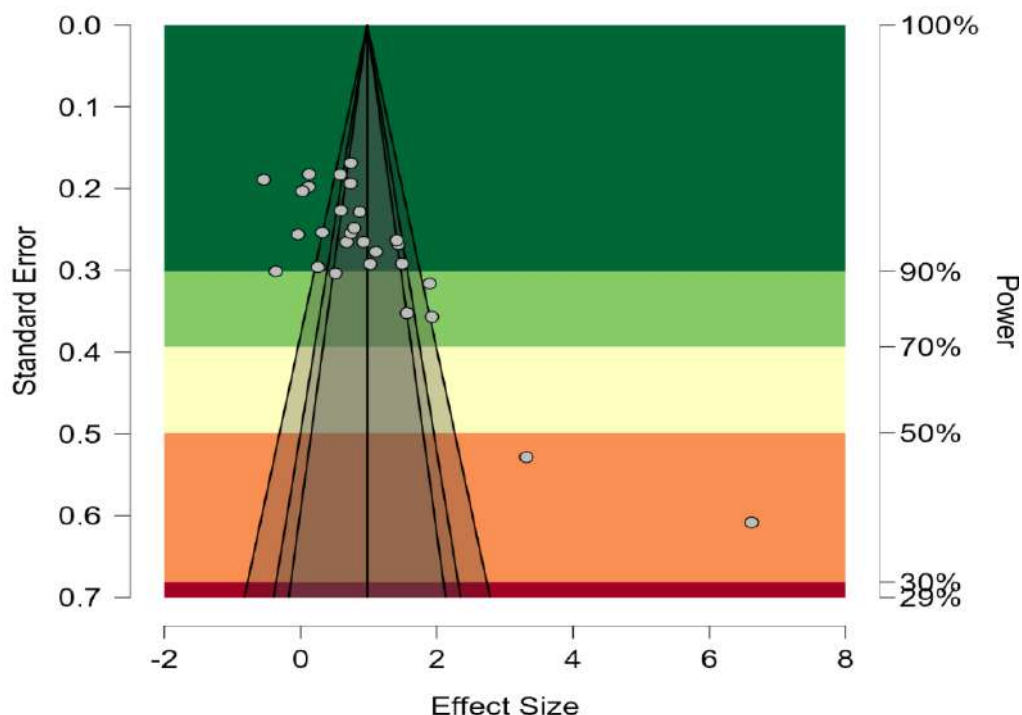


Figure 2: Funnel plot of the studies

Statistical tests provided further evidence of funnel-plot asymmetry. The meta-regression test was significant, $z = 7.70$, $p < .01$, with an estimated limit value of -2.05 , 95% CI $[-2.83, -1.27]$. The weighted regression test was also significant, $t(26) = 4.98$, $p < .01$, with an estimated limit value of -1.40 , 95% CI $[-2.28, -0.53]$. These findings indicate systematic differences in effect estimates across levels of study precision. However, funnel-plot asymmetry should not be interpreted as evidence of publication bias alone. It may also result from differences in sample size, methodological quality, intervention and comparison conditions, outcome measures, or genuine variation in intervention effects. This interpretation is particularly relevant because substantial heterogeneity was observed across the studies, $Q_{\epsilon}(27) = 275.66$, $p < .001$, $I^2 = 95.63\%$, 95% CI $[93.40\%, 98.05\%]$, and $\tau^2 = 1.346$. Therefore, the significant asymmetry tests suggest the presence of small-study effects, but they do not establish that selective publication is the sole explanation. Table 2 presents the Funnel Parameter Estimates, and Table 3 presents the Funnel-plot asymmetry test.

Table 2: Funnel Parameter Estimates

Parameter	Estimate	Lower		p-value
		95% CI	Upper 95% CI	
μ (mean effect size)	0.9774	0.5346	1.42	< .001
τ (between-study variance)	1.16	0.9334	1.761	< .001

Table 3: Funnel-plot asymmetry test

Funnel-plot asymmetry test	Estimate	Test statistic	p	95% CI
Meta-regression test	-2.05	$z = 7.70$	< .01	$[-2.83, -1.27]$
Weighted regression test	-1.40	$t(26) = 4.98$	< .01	$[-2.28, -0.53]$

4.3 Forest Plot Analysis

A forest plot was generated to display the individual study Hedges' g estimates and their corresponding 95% confidence intervals. Most studies showed positive effect estimates, with many falling between approximately 0.5 and 2.0. However, the magnitude of the effects varied considerably across studies. Some studies reported relatively large estimates, indicating substantial variation in the observed effects. The confidence intervals also differed in width. Studies with narrower intervals provided more precise estimates, whereas wider intervals indicated greater uncertainty. The variation in effect estimates and confidence intervals suggests differences in the magnitude and precision of the intervention effects across studies. The forest plot therefore provides a visual overview of the distribution of individual study effects and their uncertainty. Figure 3 presents the Forest plot of the random-effects meta-analysis results.

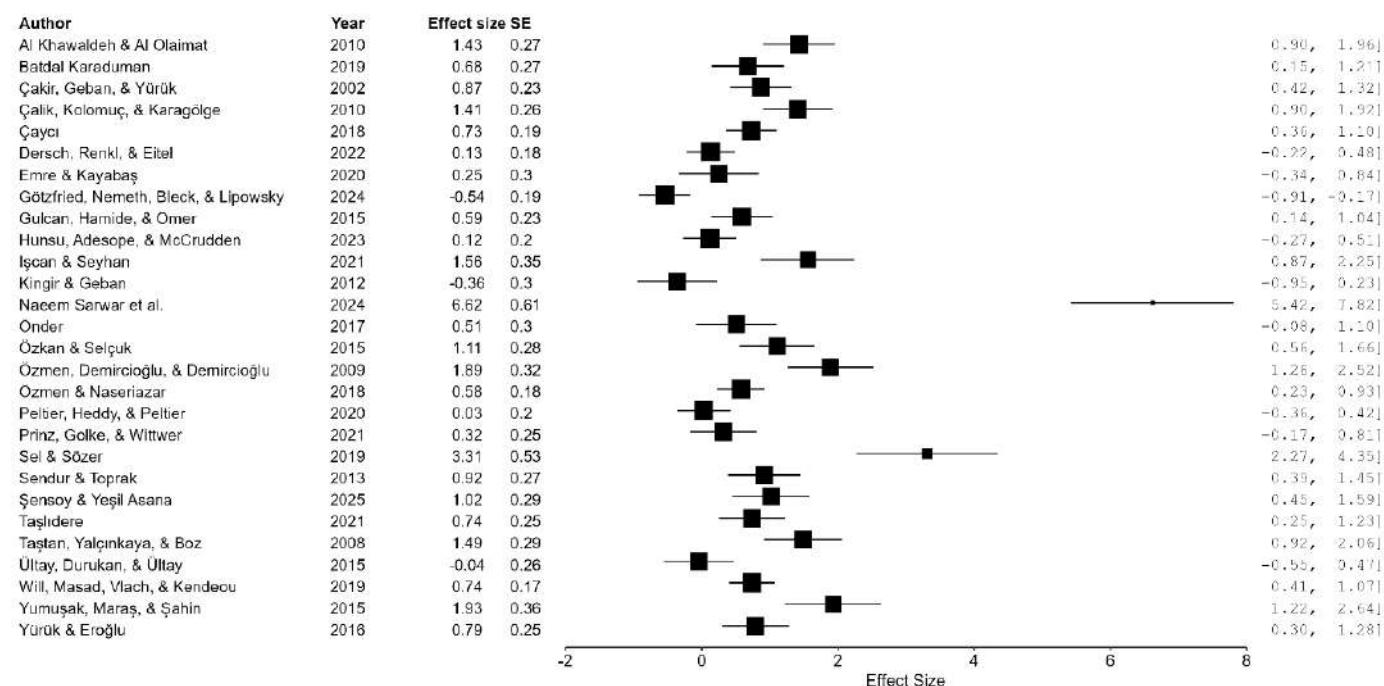


Figure 3: Forest plot of the random-effects meta-analysis results

4.4 Heterogeneity analysis

Between-study heterogeneity was assessed using Cochran's Q statistic, I^2 , and the estimated between-study variance. The Q test was statistically significant, $Q(27) = 275.66$, $p < .001$, indicating substantial variability in the effect sizes across the 28 studies. The estimated between-study standard deviation was $\tau = 1.160$ (95% CI [0.933, 1.761]), while the between-study variance was $\tau^2 = 1.346$. The I^2 statistic was 95.63% (95% CI [93.40%, 98.05%]), indicating that approximately 95.6% of the observed variability was attributable to differences between studies rather than sampling error. These findings demonstrate substantial heterogeneity and indicate that the true effects varied considerably across studies. Accordingly, a random-effects model was used to estimate the pooled intervention effect. Table 4 presents the model summary of meta-analytic tests.

Table 4: Model Summary of Meta-Analytic Tests

Meta-analytic test	Test statistic	p
Heterogeneity	$Q(27) = 275.66$	$< .001$
Pooled effect	$t(27) = 4.08$	$< .001$

4.5 Pooled effect of conceptual change texts

The random-effects meta-analysis produced a positive pooled Hedges' g of 0.9774 (SE = 0.2398, 95% CI [0.4854, 1.4690]). The test of the pooled effect was statistically significant, $t(27) = 4.08$, $p < .001$, indicating that the pooled effect differed significantly from zero. Thus, across the included studies, text-based conceptual change interventions were associated with higher learning outcomes than the respective comparison conditions. Given the substantial heterogeneity identified across studies, the pooled estimate should be interpreted as an average effect across varying study contexts and intervention conditions. Table 5 presents the Meta-analytic estimates.

Table 5. Meta-Analytic Estimates

<i>Statistic</i>	<i>Estimate</i>	<i>95% CI</i>	<i>95% PI</i>
Pooled effect, g	0.977	[0.485, 1.469]	[-1.454, 3.409]
τ	1.16	[0.933, 1.761]	
τ^2	1.346	[0.871, 3.101]	
I^2 (%)	95.63	[93.40, 98.05]	

4.6 Moderator Analysis

A mixed-effects meta-regression was conducted to examine whether publication year, country, and research design explained variation in the observed Hedges' g estimates. Fixed effects were tested using the Knapp and Hartung adjustment. Publication year was not a statistically significant moderator, $F(16, 6) = 0.51$, $p = .87$, indicating no significant variation in effect sizes across publication years. Research design was also not statistically significant, $F(1, 6) = 1.04$, $p = .35$, suggesting that the type of research design did not systematically account for differences in the observed effects. Country was statistically significant at the conventional .05 level, $F(4, 6) = 4.41$, $p = .05$, indicating that effect sizes varied across the country categories included in the analysis. Overall, the results identified country as a significant moderator, whereas publication year and research design did not significantly explain variation in the observed intervention effects. Table 6 presents the meta-regression results.

Table 6. Meta-Regression Summary

<i>Moderator</i>	<i>F</i>	<i>df₁</i>	<i>df₂</i>	<i>p</i>
Year	0.51	16	6	0.87
Country	4.41	4	6	0.05
Design	1.04	1	6	0.35

5.0 DISCUSSION

This meta-analysis examined the effectiveness of conceptual change texts (CCTs) on students' learning outcomes across 28 studies. The random-effects model produced a statistically significant positive pooled effect, indicating that CCTs were associated with improved learning outcomes compared with the respective comparison conditions. However, the very high between-study heterogeneity indicates that their effects varied substantially across contexts. The finding is consistent with previous meta-analyses. Armağan et al. (2017), based on 42 studies, reported a positive effect of CCTs on academic achievement. Similarly, Pacaci et al. (2024) found a large overall effect for conceptual change strategies, while Schroeder and Kucera (2022) reported a significant effect of refutation texts on learning outcomes across 44 independent comparisons. Dersch et al. (2026) also found positive effects of personalized refutation texts on conceptual change among in-service and student teachers who held targeted misconceptions. Together, these findings provide converging evidence for the potential of text-based approaches to support conceptual change.

The positive effects may be explained by the way CCTs directly address learners' prior knowledge and alternative conceptions. Rather than simply presenting scientifically accepted information, these texts identify common alternative explanations, provide evidence that challenges their adequacy, and introduce scientifically acceptable explanations. This process can create cognitive conflict and encourage learners to reconsider and reorganize their existing knowledge. The effectiveness of such texts may therefore depend on how effectively they connect learners' prior conceptions with the new scientific explanation. Despite the positive pooled effect, the very high heterogeneity indicates considerable variation in intervention effects. This finding is broadly consistent with Pacaci et al. (2024). Differences in text structure, content, explicitness, use of refutation, evidence, opportunities for reflection, and intervention duration may contribute to this variability. Differences in learners' age, prior knowledge, reading ability, strength of alternative conceptions, instructional setting, teacher involvement, assessment instruments, and comparison conditions may also influence outcomes.

The moderator analysis showed that publication year and research design did not significantly explain variation in effect sizes. This finding is consistent with Armağan et al. (2017), who also found no significant differences associated with publication date. In contrast, country was a statistically significant moderator at the omnibus level, indicating variation in effect sizes across the countries represented in the analysis. However, the relatively small number of studies within some country categories warrants cautious interpretation. The significant tests of funnel-plot asymmetry suggest potential small-study effects. However, asymmetry does not establish publication bias because it may also result from differences in study precision, methodology, outcome measures, sample characteristics, intervention conditions, or genuine variation in effects. This finding therefore requires cautious interpretation when considering the robustness of the pooled estimate.

6.0 CONCLUSION

This meta-analysis found a statistically significant positive average effect of text-based conceptual change interventions on students' learning outcomes. However, the very high heterogeneity ($I^2 = 95.63\%$) and prediction interval ranging from -1.454 to 3.409

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indicate substantial variation in effects across studies. Publication year and research design did not significantly moderate the effects, whereas country showed a significant omnibus association.

Evidence of funnel-plot asymmetry also indicated potential small-study effects. Overall, the findings suggest that CCTs can support learning and conceptual change, but their effectiveness is not uniform across instructional and research contexts. The findings have implications for science teachers, curriculum developers, and educational researchers. Science teachers may consider using CCTs when teaching concepts associated with persistent alternative conceptions. CCTs may be more effective when integrated with complementary approaches such as classroom discussion, inquiry-based activities, demonstrations, experiments, concept mapping, and opportunities for students to explain and apply revised understandings.

Teachers should assess students' prior conceptions before selecting or developing conceptual change texts. This information can help ensure that the texts address specific conceptual difficulties. CCTs should also be adapted to learners' educational levels, subject areas, language, cultural backgrounds, and instructional contexts. For curriculum developers, the substantial heterogeneity identified in this meta-analysis highlights the need for flexible materials that can be adapted to different learning conditions. Future research should examine specific characteristics of CCTs and learner or instructional factors that may explain differences in effectiveness. Greater attention to intervention duration, text design, teacher mediation, learner characteristics, and assessment methods could help clarify the conditions under which conceptual change texts are most effective.

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