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The effect of computational thinking on creativity: A meta-analysis for teaching strategies

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Abstract

This meta-analysis aims to examine the relationship between computational thinking (CT) and creativity, to understand the effect of CT on creativity, and to evaluate this effect in different contexts to develop applicable recommendations for teaching strategies. A literature search was conducted in the Web of Science and Scopus databases during the fall of 2024 using the keywords “computational thinking” OR “CT” and “creativity” OR “creative thinking,” and it was filtered for full-text articles published in English after 2016. This search identified 410 studies, of which seven studies, with eight effect size, met the inclusion criteria. The included studies provided the necessary experimental data (Mean, SD and t of F-value) for measuring creativity after CT intervention. Effect sizes were calculated using Hedges’s g under a random effects model to correct for small sample bias; heterogeneity was assessed with Q and I^2 statistics. Publication bias was analyzed by funnel plot and Duval and Tweedie’s Trim and Fill test, confirming the reliability of the findings. In this meta-analysis, moderator variables such as publication year, country, discipline, grade, CT activity and intervention duration were considered. By identifying in which contexts the effects are stronger or weaker through these moderators, the study guides the design and implementation of CT activities in education. The results showed that CT has a significant and positive effect on creativity (Hedges’s g = 0.68) with moderating disciplines, grade and year. This study contributes to a deeper understanding of how CT can be integrated into educational environments to foster creativity, providing both theoretical and practical contributions to the field of technology.

Keywords: Computational thinking, creativity, meta-analysis, teaching strategies.

Introduction

In today’s rapidly changing digital age, computational thinking (CT) and creativity are increasingly recognized as essential 21st-century skills for innovative problem-solving and knowledge generation (da Silva, de Melo & Tedesco, 2020). While creativity is traditionally defined as the ability to generate original and valuable outcomes (Torrance, 1966), CT, as described by Wing (2006), is a cognitive practice that uses core concepts like decomposition and abstraction to address complex problems systematically. Both are considered versatile cognitive skills that can be nurtured across disciplines, from STEM to the arts (Kalelioğlu & Gülbahar, 2015; Beghetto, 2021).

The relationship between CT and creativity has drawn scholarly attention, with research highlighting a reciprocal link: CT practices can foster creativity (Seo & Kim, 2016) and creative

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approaches can aid in solving computational problems (Liu & Lu, 2002). However, this connection remains underexplored from a pedagogical perspective. A review by Israel-Fishelson and Hershkovitz (2022) points out that existing studies are often limited to STEM contexts and narrow geographic locations, suggesting a need for a broader and more integrative examination of the CT-creativity link.

To address these limitations, the present meta-analysis systematically investigates the relationship between CT and creativity. It aims to clarify the effect of CT across different contexts by analyzing various moderators, including discipline, grade level, and intervention duration. This comprehensive approach builds on previous meta-analyses (Montuori et al., 2024; Fidai, Capraro, & Capraro, 2020; Zhang et al., 2024) to provide a clearer picture of how these skills interact and to offer applicable recommendations for instructional strategies.

The link between CT and creativity

Research highlights a bidirectional relationship between CT and creativity (Israel-Fishelson et al., 2019; Fragapane & Standl, 2021). Creativity can act as a catalyst for solving algorithmic problems, producing computational artefacts, and generating knowledge (Liu & Lu, 2002). Conversely, CT practices such as observation, imagination, and abstraction have been shown to foster creativity (Seo & Kim, 2016; Macann & Yadav, 2025; Yadav & Cooper, 2017).

Two main approaches have emerged in the literature. The first examines creativity within CT, focusing on computational artefacts and their creative processes. Platforms like Scratch and Alice provide opportunities for learners to express creativity through problem-solving (Knobelsdorf & Romeike, 2008). The second investigates whether CT instruction fosters creativity (Seo & Kim, 2016) or whether creativity supports CT skill development (Pérez Poch et al., 2016). Recent studies reinforce this reciprocal relationship, showing that CT appears to enhance creativity in diverse educational contexts.

Prior meta-analyses and research gaps

Prior meta-analyses have provided valuable insights. Montuori et al. (2024) reported that both activity type and age significantly shape outcomes, suggesting that structured coding benefits younger learners while unstructured approaches are more effective for older students. Similarly, Fidai, Capraro, and Capraro (2020) found that grade level and intervention duration moderate the effectiveness of CT, with certain tools like Arduino and Scratch yielding powerful benefits. Zhang, Guan, and Hu (2024) showed that project-based learning enhances CT, though its impact varies by developmental stage. Collectively, these studies suggest that aligning CT interventions with developmental characteristics and learning contexts may improve their effectiveness.

Despite these insights, comparisons remain challenging due to variation in how creativity is conceptualized and measured, as well as the diversity of CT interventions (Fidai, Capraro, & Capraro, 2024; Montuori et al., 2024). To address these gaps, the present meta-analysis systematically examines how CT activities, grade levels, and intervention durations influence creativity. It further incorporates additional moderators such as discipline, publication year, and country to capture cross-cultural and temporal variation. This comprehensive approach helps to clarify the overall CT-creativity relationship and provides a basis for testing hypotheses in this study.

Research hypothesis

This study investigates the impact of CT on creativity through a meta-analytical approach, with particular attention to various moderating factors that may influence this relationship. In doing so, the study aims to address the following hypotheses:

(H1) CT has a positive effect on creativity in education.
(H2) Discipline is a positive moderator of the effect of computational thinking on creativity.
(H3) Grade is a positive moderator of the effect of CT on creativity.
(H4) CT activity is a positive moderator of the effect of CT on creativity.
(H5) The intervention duration is a positive moderator of the effect of CT on creativity.
(H6) Publication year is a positive moderator of the effect of computational thinking on creativity.
(H7) Country is a positive moderator of the effect of computational thinking on creativity.

Method

This study used meta-analysis method to examine the effect of CT on students' creativity within the educational domain. Grounded in a comprehensive literature review, meta-analysis is frequently defined as the "analysis of analyses" in the academic literature. The results from this meta-analysis confirm that CT significantly enhances creativity in education while also highlighting (Glass, 1976).

Review strategy and criteria for inclusion

The literature search was conducted in Web of Science and Scopus databases during the fall of 2024 using the keywords "computational thinking" OR "CT" and "creativity" OR "creative thinking" in the title and abstract. To ensure transparency and rigour, a systematic review procedure was followed. Two independent researchers searched and applied the inclusion and exclusion criteria. Discrepancies were resolved through consensus discussions, thereby establishing inter-rater reliability.

The results were filtered for full-text articles published in English after 2016. In total, 410 studies were identified, with 184 from Scopus and 206 from Web of Science. Studies were eligible for inclusion if they reported the necessary experimental data (Mean, Standard Deviation [SD] and *t* or *F-values*) to measure creativity after a CT intervention. In addition, having an experimental design with at least one control group was also determined to be an important requirement. Based on these criteria, seven studies were included in the meta-analysis.

Coding and statistics process

In the coding process, a coding table was prepared to examine the characteristics of the studies and to ensure accurate statistical analysis. This table includes moderators such as research bibliography, year of publication, country of study, discipline, CT activity used for intervention, grade, intervention duration, and quantitative data (Mean and SD for both groups with t or F-values). After the coding process was completed, statistical procedures were performed to calculate the effect size. The statistical procedures were carried out in [Comprehensive Meta-Analysis (CMA)]. Effect sizes were calculated using Hedges's g with 95% confidence intervals under a random effects model to correct for small sample bias; heterogeneity was assessed with Q and I^2 statistics. The higher the I-value, the higher the heterogeneity. 0-25 indicates low heterogeneity, 25-75% suggests moderate heterogeneity, and 75-100% indicates considerable heterogeneity (Higgins, Judge, & Ferris, 2003). Publication bias was analyzed by funnel plot and Duval and Tweedie's Trim and Fill test, confirming the reliability of the findings.

To analyze the effects of moderators in the study, the Q between statistic was employed for six moderator variables: discipline, grade, CT activity, intervention duration, publication year, and country. A specific methodological approach was necessary for the intervention duration variable due to the disparate and non-uniform durations reported across the included studies. This categorization was based on a direct analysis of the intervention durations reported in the studies, revealing natural similarities and differences within the dataset. For instance, the values of 6 and 8 hours demonstrated a close similarity, forming a distinct "short-duration" cluster. Similarly, the 10, 16, and 18-hour durations, while slightly more varied, clustered together as a coherent "medium-duration" group. The 28-hour intervention, being significantly longer than all others, naturally stood as its own "long-duration" category. This approach was a methodological necessity for conducting a statistically valid and meaningful analysis because there were insufficient studies per group when analysed individually.

Publication bias

The meta-analysis found no evidence of publication bias, and the funnel plot showed no bias (Figure 1), which demonstrates symmetry. The results of Duval and Tweedie's Trim and Fill test, using the random effect model for seven research studies, indicated that the effect size showed no difference between the observed and fixed effect sizes. There was no finding indicating data loss. Accordingly, it can be said that the results obtained in the meta-analysis are reliable and not affected by any publication bias or data imbalance.

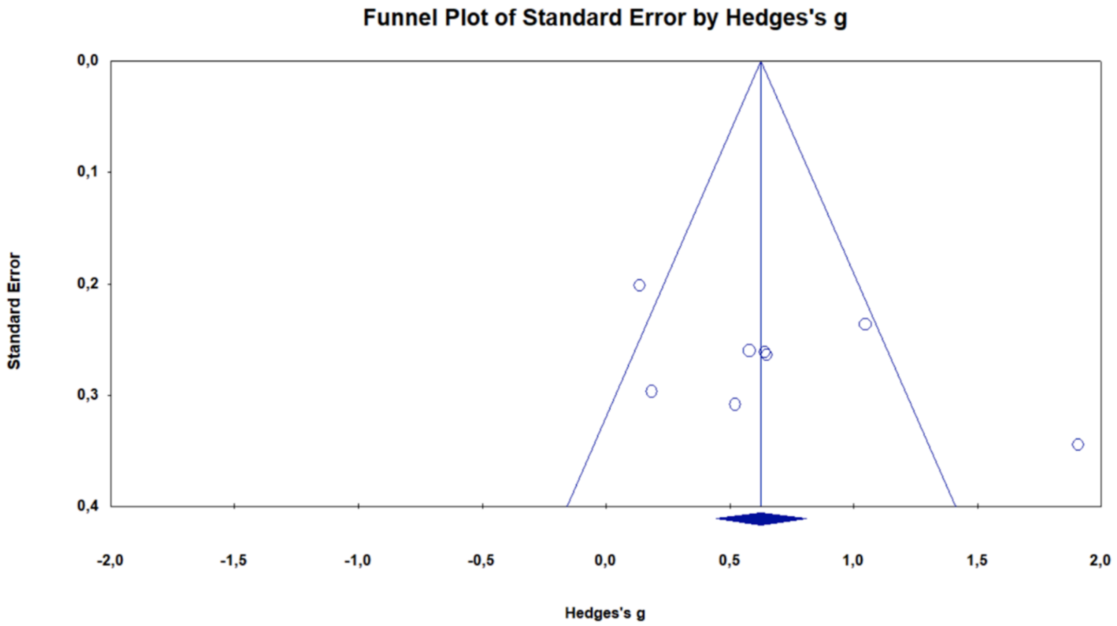

Figure 1 Funnel plot of standard error by Hedges's g

Results

Overall effect size and heterogeneity

The results of the overall effect size and heterogeneity analysis are presented in Table 1. A significant Q statistic ($Q = 25.28$, $p < .001$) and high level of heterogeneity ($I^2 = 72.31\%$) indicated substantial variability among the effect sizes. Accordingly, a random-effects model was adopted for the meta-analysis.

Table 1 Overall effect size and heterogeneity test

k	n	Hedges's g	%95 CI Lower-Upper	Test of null Z	p	Q	I^2
8	480	0.68	[0.33-1.03]	3.82	.000	25.28*	72.31*

*p<.001; under random-effects model; k total number of effect sizes

As shown in Table 1, the overall effect size was moderate to large (Hedges's g = 0.68, 95% CI [0.33, 1.03], p < .001), indicating a significant positive effect of computational thinking (CT) on creativity in educational contexts. These results support H1, confirming that CT has a positive impact on creativity in education. The forest plot of all the included effect sizes is shown in Figure 2.

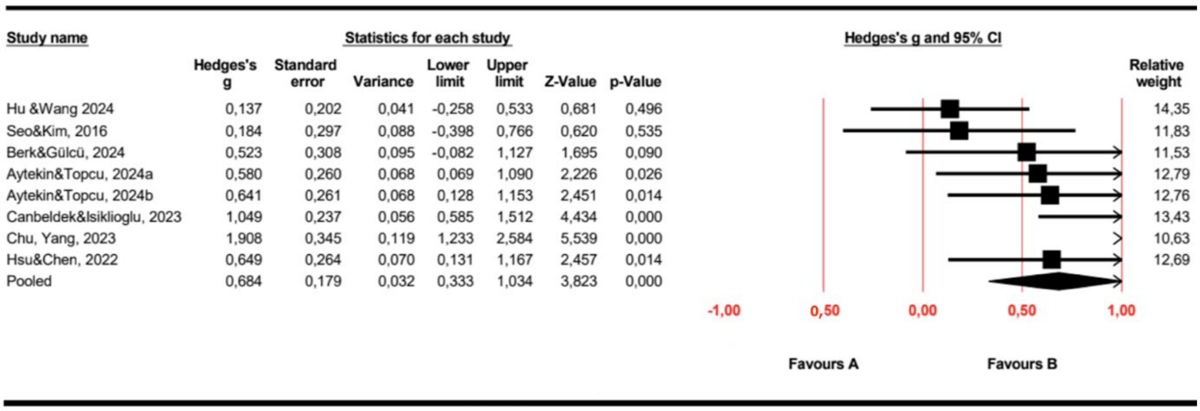

Figure 2 Forest plot for the random-effects model

Moderator analyses

To further examine the variability in effect sizes, moderator analyses were conducted to identify factors that may influence the relationship between CT and creativity. The results are summarized in Table 2.

Table 2 All moderator analysis results

Moderators	k	Hedges's g	%95 CI Lower-Upper	Test of null Z	p	Qbetween
Discipline						11.52*
STEAM	2	1.38	[0.87-1.90]	5.27	.000**	
Computer Science	1	0.64	[-0.05-1.34]	1.81	.060	
Science	2	0.61	[0.11-1.10]	2.43	.010*	
Mathematics	2	0.28	[-0.19-0.76]	1.17	.230	
Geometry	1	0.18	[-0.56-0.93]	0.48	.630	
Grade						25.18**
Preschool	1	1.04	[0.58-1.51]	4.34	.000**	
Elementary	2	0.15	[-0.17-0.47]	0.91	.360	
Middle school	3	0.58	[0.27-0.89]	3.70	.000**	
High school	1	1.90	[1.23-2.58]	5.53	.000**	
University	1	0.64	[0.13-1.16]	2.45	.010**	
CT activities						2.37
Plugged	3	0.97	[0.29-1.65]	2.79	.000**	
Unplugged	2	0.37	[0.16-0.41]	0.93	.340	
Block-based	1	0.18	[0.35-0.99]	0.30	.750	
Block-based+ unplugged	1	1.04	[0.32-0.07]	1.83	.060	

Board game	1	0.64	[0.34-0.49]	1.11	.260	
Intervention Duration						3.17
Short	2	0.37	[-0.24-0.99]	1.18	.230	
Medium	5	0.91	[0.49-1.32]	4.29	.000*	
Long	1	0.18	[-0.76-1.13]	0.38	.700	
Publication Year						10.62*
2016	1	0.18	[-0.56-0.93]	0.48	.630	
2022	1	0.64	[-0.05-1.35]	1.81	.070	
2023	2	1.38	[0.86-1.90]	5.25	.000**	
2024	4	0.44	[0.10-0.79]	2.53	.010*	
Country						5.32
China	1	0.13	[-0.68-0.95]	0.32	.740	
Korea	1	0.18	[-0.73-1.10]	0.39	.690	
Taiwan	2	1.21	[0.55-1.86]	3.61	.000**	
Turkey	4	0.70	[0.26-1.15]	3.13	.002**	

*p<.05, **p<.01

Discipline

Discipline significantly moderated the effect of CT on creativity (Qbetween = 11.52, p < .05), supporting H2. The strongest effect was observed in STEAM contexts (g = 1.38, 95% CI [0.87–1.90], p < .01), whereas Mathematics (g = 0.28, 95% CI [–0.19–0.76], p = .23) and Geometry (g = 0.18, 95% CI [–0.56–0.93], p = .63) showed minor, non-significant effects. These results suggest that CT interventions embedded in interdisciplinary contexts such as STEAM may be particularly effective in fostering creativity.

Grade level

Grade level also significantly moderated the relationship between CT and creativity (Qbetween = 25.18, p < .01), supporting H3. The most substantial effects were found at the high school level (g = 1.90, 95% CI [1.23–2.58], p < .01) and preschool level (g = 1.04, 95% CI [0.58–1.51], p < .01). In contrast, elementary school interventions yielded a small, non-significant effect (g = 0.15, 95% CI [–0.17–0.47], p = .36). These results highlight the importance of aligning CT interventions with learners' developmental stages

CT activity type

No significant differences were found between CT activity types (Qbetween = 2.37, p > .05), not supporting H4. Nevertheless, subgroup anaylses indicated that plugged activities (g = 0.97, 95% CI [0.29–1.65], p < .01) and block-based + unplugged combinations (g = 1.04, 95% CI [0.32–1.83], p = .06) had relatively higher effect sizes. While these findings are not statistically conclusive, they suggest that digital or combined activity formats may hold potential for supporting creativity, warranting further investigation.

Intervention duration

Although differences by intervention duration were not statistically significant (Qbetween = 3.17, p > .05), thus not supporting H5. However, medium-duration interventions (10–20 hours) produced a significant effect (g = 0.91, 95% CI [0.49–1.32], p < .01), whereas shorter (<10 hours) and longer (>20 hours) interventions did not yield significant effects. This pattern suggests a possible optimal intervention duration for enhancing creativity, which should be examined in future studies.

Publication year

Publication year significantly moderated the findings (Qbetween = 10.62, $p < .05$), supporting H6. Studies published in 2023 exhibited the largest effect size ($g = 1.38$, 95% CI [0.86–1.90], $p < .01$), which may reflect methodological advances and the increasing integration of CT into creativity-oriented pedagogies.

Country

Country differences were not statistically significant (Qbetween = 5.32, $p > .05$). However, subgroup analyses revealed that Taiwan ($g = 1.21$, 95% CI [0.55–1.86], $p < .01$) and Turkey ($g = 0.70$, 95% CI [0.26–1.15], $p < .01$) reported significant effects. These results suggest potential contextual and cultural influences. However, the relatively small number of studies per country limits the generalizability of these findings and underscores the need for further comprehensive, country-level investigations.

Conclusion and discussion

This meta-analysis systematically examined the relationship between CT and creativity in education, while also testing for potential moderating factors to develop applicable recommendations for teaching strategies. The overall findings indicate that CT has a positive effect on creativity, with a moderate-to-large effect size, supporting H1. These results are consistent with previous research (Hershkovitz et al., 2019; Israel-Fishelson et al., 2021; Macann & Yadav, 2025; Yadav & Cooper, 2017).

The results showed that discipline significantly moderated the effect of CT on creativity, with powerful effects in STEAM contexts. This resonates with arguments that CT is not limited to technical domains (Wing, 2006) and with recent findings that interdisciplinary approaches can support creative thinking by combining computational and artistic practices (Castro-Zubizarreta, García-Lastra, & del Río, 2024; Habeeb, Alnajjar, & Jafer, 2024; Kwon & Li, 2025; Li & Tee Oon, 2024). This is further supported by studies showing that integrating CT into interdisciplinary projects significantly enhances creativity, especially in STEAM contexts (Weng et. al., 2024; Yunianto et al., 2025). By contrast, more minor, non-significant effects in Mathematics and Geometry suggest that more targeted pedagogical strategies may be needed in narrowly defined disciplines. These findings underscore the importance of teaching strategies that encourage educators to use CT not just as a technical tool, but as an integrated skill that supports artistic and creative problem-solving across disciplines. Extending this contextual perspective, country differences were not statistically significant, though subgroup analyses indicated higher effects in Taiwan and Turkey. While these findings may suggest that local contexts influence outcomes, the small number of studies per country prevents strong conclusions. Instead, they underscore the need for further cross-cultural research to better understand how educational systems and cultural factors shape CT-creativity relationships (Israel-Fishelson & Hershkovitz, 2022; Tariq et al., 2025).

Grade level also emerged as a significant moderator. High school and preschool students showed stronger effects, consistent with evidence that both exploratory learning in early childhood and complex, open-ended tasks in adolescence provide fertile ground for creativity (Bers, 2020; Chalmers, 2018). Elementary school students exhibited more minor effects, which may indicate the need for more structured and developmentally tailored CT interventions at this stage. These results align with Montuori et al. (2024), who found that structured virtual and robotics activities are particularly effective for younger learners, whereas older students benefit from more unstructured approaches. This suggests that teaching strategies should adjust the difficulty and structure of interventions according to students' developmental stages, using more guided approaches for younger learners and more open-ended tasks for older ones.

For other moderators, results were more tentative. CT activity type and intervention duration did not yield statistically significant differences, although subgroup analyses suggested some promising patterns. Plugged and block-based + unplugged approaches showed relatively higher effect sizes, suggesting that combined formats may be particularly engaging, but further studies are needed to confirm this (Chen, Lai & Lin, 2020; Murcia et al., 2020; Shamir & Levin, 2022; Seo & Kim, 2016). Similarly, medium-duration interventions (10–20 hours) showed more substantial effects compared to shorter or longer ones, which may point to an optimal engagement window. While not statistically significant, the observed trends offer a practical rationale for educators to consider instructional designs that combine different learning experiences (Ji & Wong, 2025; Weng et. al., 2024) and provide students with sufficient time to adapt to the process, rather than relying on uniform or very short-term interventions.

Publication year significantly moderated the relationship, with studies published in 2023 reporting the strongest effects. This may reflect methodological advances and the growing integration of CT into creativity-focused pedagogies. Lin and Chen (2020) emphasize the importance of aligning CT practices with emerging technologies such as augmented reality and adaptive systems, which may partly explain why newer studies show larger effects. On the other hand, Weng et al. (2024) and Zhang et al. (2025) extend this finding by showing that AI-supported CT interventions produce even stronger creativity outcomes, underlining the importance of integrating AI into modern CT curricula. This also suggests that teaching strategies should consider the integration of new technologies, such as AI-supported tools, to maximize the impact on creativity.

Overall, these findings support the view that CT can contribute to creativity in educational settings but highlight that the strength of this contribution depends on multiple contextual factors. They also align with previous research emphasizing that creativity and CT may reinforce each other in reciprocal ways (Israel-Fishelson et al., 2021; Seo & Kim, 2016). These results provide empirical support for designing adaptive, context-sensitive CT curricula that aim not only to build computational skills but also to cultivate creativity.

Building on these empirical findings, this meta-analysis provides a systematic synthesis of the evidence on the relationship between CT and creativity in education. The findings confirm that CT has a generally positive effect on creativity, supporting earlier claims that computational practices can serve as a foundation for innovation and problem-solving (Brennan & Resnick, 2012; Grover & Pea, 2013). However, the magnitude of this effect varies by discipline, grade level, intervention duration, and publication year, suggesting that CT's benefits are shaped by context rather than being uniform across settings.

As demonstrated throughout the analysis, interdisciplinary approaches, particularly in STEAM, and certain developmental stages, such as preschool and high school, showed stronger effects. These findings are consistent with previous research emphasizing the role of active, developmentally appropriate, and contextually relevant learning experiences in fostering creativity (Bers, 2020). Although activity type, duration, and country did not emerge as significant moderators, observed trends—such as the potential advantages of plugged or combined activities and medium-duration interventions—point to promising directions for further study.

This synthesis also highlights gaps in the literature. The unbalanced distribution of studies across disciplines, educational levels, and cultural contexts limits the generalizability of findings and underscores the need for broader, more diverse research. For instance, while our study found that intervention duration was not a significant moderator for the effect of CT on creativity, a recent meta-analysis on CT in mathematics instruction integrated with STEAM education (Suparman et al., 2025) reported that duration was a significant factor in fostering CT skills. This discrepancy highlights the importance of considering the specific learning outcome. It shows that the duration can play a different role depending on the targeted skill (creativity or CT). It suggests that while the length of an intervention might not be critical for cultivating creativity, it is highly relevant for enhancing the CT skills themselves. This underscores the need for more nuanced research that can clarify how different instructional strategies interact with learner characteristics and target specific outcomes.

In conclusion, this study contributes to a deeper understanding of how CT can be purposefully integrated into educational environments to foster creativity. It underscores the importance of designing CT-based interventions that are sensitive to disciplinary focus, developmental stage, and cultural context, thereby offering practical insights for educators, policymakers, and researchers.

Recommendations for future research

This synthesis provides an evidence-based framework to guide future research and practice, emphasizing adaptive and context-specific CT implementation across disciplines, age groups, and global contexts. To build on these findings, we recommend several key areas for future investigation: First, longitudinal and experimental studies are needed to further explore the mechanisms underlying the CT-creativity relationship and to identify which instructional strategies best support different learner characteristics. Specifically, future research should focus on how teaching strategies can be tailored to varying developmental stages, providing more structured guidance for elementary students while offering more open-ended, complex tasks for high school learners.

Second, research should expand across diverse cultural and educational contexts to enhance the generalizability of findings. The trends observed in specific countries, such as Taiwan and Turkey, suggest that cultural and educational factors may influence outcomes, necessitating more comprehensive, country-level studies to clarify these influences. This will provide valuable insights for designing culturally sensitive and effective teaching strategies.

Third, given the significant moderating effect of publication year and the trend toward stronger effects in recent studies, future research should examine the role of emerging technologies. Specifically, there is a growing need for studies that investigate how teaching strategies integrating tools like artificial intelligence (AI) or augmented reality can be leveraged to maximize creativity gains in CT education.

Overall, this study contributes to a deeper understanding of how CT can be purposefully integrated into educational environments to foster creativity. It underscores the necessity of designing CT-based curricula and learning experiences that are both developmentally appropriate and contextually relevant. Future work should continue to refine theoretical models and develop scalable, evidence-based approaches for integrating CT into diverse educational settings in ways that meaningfully promote creativity.

Statement of researchers

In this section, the authors provide transparent information regarding individual contributions, potential conflicts of interest, and acknowledgements related to the development and publication of the study.

Researchers' contribution rate statement

This study was conducted within the scope of a graduate-level Educational Statistics course. The research emerged as a result of student-led work under the supervision and academic guidance of the third author. The first and second authors, who are graduate students, were responsible for data collection, coding, and statistical analysis. They also prepared the initial draft of the report. The third author led the final writing of the manuscript and oversaw the overall structure, academic rigour, and reporting of the meta-analytic procedures. The first two authors contributed equally to this work.

Conflict statement

The authors declare that there is no conflict of interest regarding the publication of this study.

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