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Article abstract

Metacognition refers to the capacity to comprehend and manage one's own cognitive processes, enabling the recognition of biases and presumptions that might influence them. Numerous published studies indicate that through metacognition, enhancements in critical-thinking skills allow individuals to query information, assess data, and make more evidence-grounded decisions—a cornerstone of critical and analytical thinking. This study aims to delineate the association between metacognition and critical-thinking skills via a meta-analysis. The data sources encompass articles published on Scopus between 2013 and 2023, identified using the keywords "Metacogni*" AND "Critical Thinking". This meta-analysis included 60 studies from diverse global locations. Employing a random-effects model, the analysis evaluated both effect size and potential publication biases using Jamovi 2.2.5 and OpenMEE software. The outcomes affirm a significant correlation between metacognition and critical-thinking skills, highlighting a robust effect of metacognition on critical-thinking skills, reflected in a significant measure of r = 0.649. Thus, increasing metacognitive abilities will improve critical-thinking abilities.

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Can Critical-thinking Skills be Measured by Analyzing Metacognition?

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Abstract

Metacognition refers to the capacity to comprehend and manage one's own cognitive processes, enabling the recognition of biases and presumptions that might influence them. Numerous published studies indicate that through metacognition, enhancements in critical-thinking skills allow individuals to query information, assess data, and make more evidence-grounded decisions—a cornerstone of critical and analytical thinking. This study aims to delineate the association between metacognition and critical-thinking skills via a meta-analysis. The data sources encompass articles published on Scopus between 2013 and 2023, identified using the keywords *"Metacogni*" AND "Critical Thinking"*. This meta-analysis included 60 studies from diverse global locations. Employing a random-effects model, the analysis evaluated both effect size and potential publication biases using Jamovi 2.2.5 and OpenMEE software. The outcomes affirm a significant correlation between metacognition and critical-thinking skills, highlighting a robust effect of metacognition on critical-thinking skills, reflected in a significant measure of r = 0.649. Thus, increasing metacognitive abilities will improve critical-thinking abilities.

Introduction

21st-century skills encompass a range of essential attributes crucial for navigating modern life, particularly in academia and prospective professions. Among these, ways of thinking form a fundamental category. This means creativity, innovation, critical thinking, problem-solving, decision-making, and metacognition (Maoulida et al., 2023; Rahman, 2019). Indeed, based on the information provided, metacognition and creative-thinking skills are identified as integral components within the category of ways of thinking, which fall under the umbrella of 21st-century skills.

The development of these critical-thinking skills is crucial in shaping individuals who are not only capable, but also competitive in the future. These elements play a pivotal role in nurturing high-quality individuals equipped with the ability to analyze, problem-solve, and think innovatively, enhancing their capacity to thrive in a competitive environment (Sukarno & Musyafa, 2021). Over the past two decades around the world, critical-thinking skills have become a highly valued employee competency (McMillan et al., 2022) and a major goal of education (Sulaiman, 2018). Utilizing metacognitive strategies and honing this ability has shown a positive correlation with academic performance. Students who employ these approaches tend to achieve better results in their scholastic pursuits, as these skills empower them to effectively comprehend, analyze, and apply knowledge, ultimately enhancing their performance in various academic tasks and assessments (Trigueros et al., 2020). Clearly, critical-thinking skills significantly contribute to the enhancement of students' reasoning abilities. By encouraging the evaluation of information, questioning assumptions, and analyzing evidence, critical thinking cultivates a more robust and logical approach to reasoning. Students proficient in this way are better equipped to make sound judgments, solve complex problems, and articulate their thoughts with clarity, thereby refining their overall reasoning skills (Murtadho, 2021). These findings conclude that metacognition and critical thinking are two things that are important, not only in learning, but are also necessary in the future working world.

Metacognition and critical-thinking skills are closely interconnected. Metacognition involves understanding one's own thinking processes—being aware of how one thinks and learns. Critical thinking, on the other hand, involves analyzing, evaluating, and reasoning about information. Metacognition enables individuals to reflect on their thinking, recognize biases, and monitor their understanding of a subject. These self-awareness and monitoring processes significantly contribute to the development of critical-thinking skills. In turn, this type of thinking encourages metacognitive practices, by prompting individuals to assess the quality of their thinking, consider alternative viewpoints, and refine their cognitive strategies. Ultimately, these two skill sets complement and reinforce each other, as metacognition aids in optimizing and improving critical-thinking abilities, while critical thinking, in turn, promotes a deeper metacognitive awareness. Metacognition is also needed in critical thinking (Sannathimmappa et al., 2022). One discovery suggested that emphasizing the enhancement of metacognitive skills has the potential to establish habits that reduce biases in students. These habits are expected to enhance students' capacity for critical thinking (Maynes, 2015). However, there are findings that metacognition is negatively correlated with critical-thinking skills (Chang et al., 2021). The varying results regarding the correlation between these two abilities necessitate a comprehensive examination of the existing literature. Presently, there is a lack of studies that systematically consolidate the link between metacognition and critical-thinking skills. This meta-analysis aims to address this gap, by endeavouring to provide a consolidated understanding of their relationship.

A meta-analysis is a methodical and numerical investigation that utilizes pre-existing studies (secondary data) to arrive at precise conclusions (Chamdani et al., 2022). Based on the information provided, it can be inferred that both metacognition and critical-thinking skills hold significance in learning and future professional contexts. The interconnected nature of these skills underscores their importance. To comprehensively understand the relationship between metacognition and critical thinking on a global scale, a meta-analysis is essential. This study aims to be the inaugural meta-analysis exploring the universality of this relationship, incorporating participants from diverse countries and academic levels. Its objective is to empirically establish and quantify the impact of the relationship between metacognition and critical-thinking skills through a quantitative meta-analysis methodology.

Method

This research employs a correlation meta-analysis approach, determining the effect size using a random-effect model. In other words, meta-analysis can be seen as an examination of multiple studies. In the realm of research, it involves analyzing numerous findings related to similar issues, aiming to draw statistical conclusions that consolidate and compare previously gathered data (Kriswanto et al., 2021).

Literature search and literature inclusion criteria

The studies in this meta-analysis were searched electronically through the Scopus database. The search was conducted using search within *article title, abstract, keyword* with search documents *"metacogni*" AND "critical thinking"* with document types of articles and proceedings. The gathered literature underwent screening based on specific criteria, primarily, inclusion, which was based on studies that were published in peer-reviewed journals or conference proceedings. Studies in the form of theses, dissertations, chapter books, and reports were excluded. Secondly, studies had to be written in English. Those that did not have full text in English were excluded. Thirdly, the studies had to have been published between 2013 and 2023. Studies prior to 2013 were excluded.

With these search keywords and inclusion criteria, 168 open access articles were found. Furthermore, the articles that had been obtained were filtered based on the criteria for which meta-correlation analysis must report r and N. There were 24 articles that met these criteria (Figure1). From these 24 articles, 60 studies were obtained to be analyzed. The process of sourcing research studies extends to the phase of acquiring those that align with, and are utilized in, the meta-analysis, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines (Moher et al., 2009; Ridwan et al., 2023).

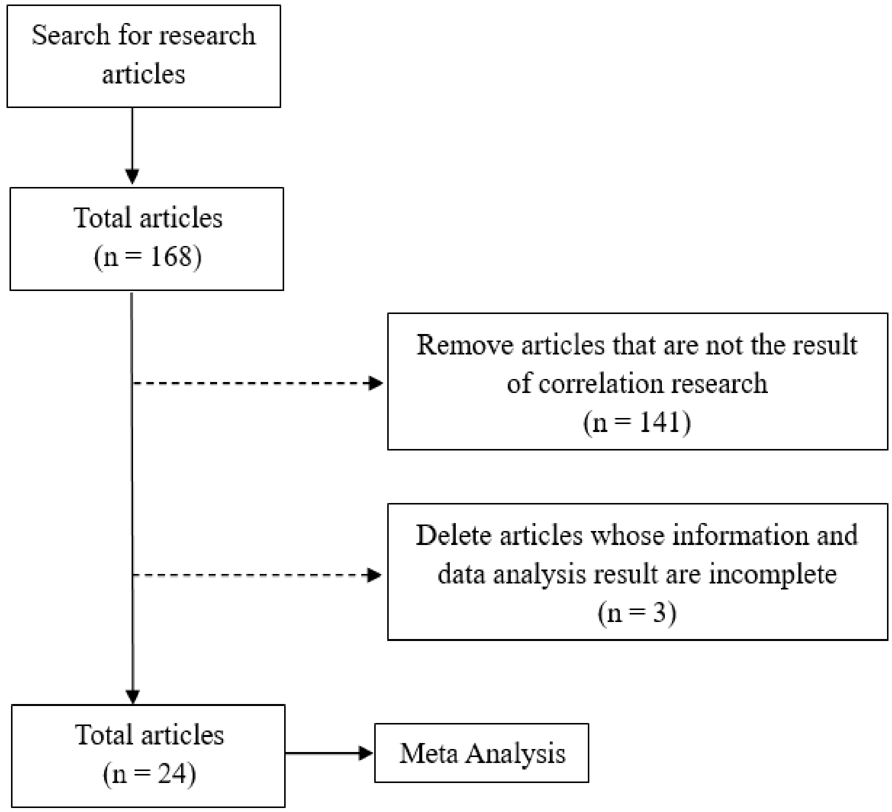

Figure 1. PRISMA flow diagram of literature search.

In more detail, the data obtained can be seen in Table 1.

Table 1. Data collection

No	Study Name	ID	*r*	*N*	Moderator Variable		
					Participant	Location	Instrument type
1	(Lehmann, 2022)	Study 1	0.260	103	College	Non-Asia	Standardized Scale
2	(Popova et al., 2022)	Study 2	0.350	147	Junior High School	Asia	Custom Scale
3	(Fernandez-Ortega et al., 2022)	Study 3	0.460	2439	Senior High School	Non-Asia	Standardized Scale
4	(Kurt & Sezek, 2022)	Study 4	0.100	36	Junior High School	Asia	Standardized Scale
5		Study 5	0.200	41	Junior High School	Asia	Standardized Scale
6		Study 6	0.530	37	Junior High School	Asia	Standardized Scale
7		Study 7	0.070	39	Junior High School	Asia	Standardized Scale
8		Study 8	0.670	32	Junior High School	Asia	Standardized Scale
9		Study 9	0.460	185	Junior High School	Asia	Standardized Scale
10	(Boran & Karakuş, 2022)	Study 10	0.730	502	Junior High School	Asia	Standardized Scale
11	(Jin & Ji, 2021)	Study 11	0.435	3000	College	Asia	Standardized Scale
12		Study 12	0.444	3000	College	Asia	Standardized Scale
13		Study 13	0.417	3000	College	Asia	Standardized Scale
14		Study 14	0.441	3000	College	Asia	Standardized Scale

15		Study 15	0.461	3000	College	Asia	Standardized Scale
16	(Usman et al., 2021)	Study 16	0.756	33	Senior High School	Asia	Custom Scale
17		Study 17	0.852	33	Senior High School	Asia	Custom Scale
18		Study 18	0.723	37	Senior High School	Asia	Custom Scale
19	(Tuaputty et al., 2021)	Study 19	0.845	137	Elementary School	Asia	Custom Scale
20		Study 20	0.720	137	Elementary School	Asia	Custom Scale
21	(Limone et al., 2020)	Study 21	0.590	450	College	Non-Asia	Standardized Scale
22		Study 22	0.593	230	College	Non-Asia	Standardized Scale
23		Study 23	0.591	220	College	Non-Asia	Standardized Scale
24	(Son, 2020)	Study 24	0.629	78	College	Asia	Custom Scale
25	(Amin et al., 2020)	Study 25	0.905	109	College	Asia	Standardized Scale
26		Study 26	0.626	109	College	Asia	Standardized Scale
27		Study 27	0.949	109	College	Asia	Standardized Scale
28		Study 28	0.828	109	College	Asia	Standardized Scale
29	(Guven & Cakir, 2019)	Study 29	0.790	468	College	Asia	Custom Scale
30		Study 30	0.770	468	College	Asia	Custom Scale
31		Study 31	0.590	468	College	Asia	Custom Scale
32		Study 32	0.480	468	College	Asia	Custom Scale
33	(Leasa, 2018)	Study 33	0.190	21	Elementary School	Asia	Custom Scale
34		Study 34	0.300	25	Elementary School	Asia	Custom Scale
35		Study 35	0.740	23	Elementary School	Asia	Custom Scale
36	(Ghasemi & Dowlatabadi, 2018)	Study 36	0.770	190	College	Asia	Standardized Scale
37	(Marquès Puig et al., 2022)	Study 37	0.209	111	College	Non-Asia	Standardized Scale
38		Study 38	0.122	111	College	Non-Asia	Standardized Scale
39		Study 39	0.063	111	College	Non-Asia	Standardized Scale
40		Study 40	0.372	111	College	Non-Asia	Standardized Scale
41		Study 41	0.229	111	College	Non-Asia	Standardized Scale
42		Study 42	0.140	111	College	Non-Asia	Standardized Scale
43	(Sadeghi et al., 2014)	Study 43	0.512	52	College	Asia	Standardized Scale
44		Study 44	0.533	50	College	Asia	Standardized Scale
45	(Teng & Yue, 2023)	Study 45	0.520	664	College	Asia	Standardized Scale
46		Study 46	0.575	664	College	Asia	Standardized Scale
47		Study 47	0.592	664	College	Asia	Standardized Scale
48		Study 48	0.586	664	College	Asia	Standardized Scale
49		Study 49	0.519	664	College	Asia	Standardized Scale
50		Study 50	0.526	664	College	Asia	Standardized Scale
51	(Karaoğlan-Yilmaz et al., 2019)	Study 51	0.345	244	College	Asia	Standardized Scale
52	(Arslan, 2015)	Study 52	0.600	390	College	Asia	Custom Scale
53		Study 53	0.580	390	College	Asia	Custom Scale
54		Study 54	0.640	390	College	Asia	Custom Scale
55		Study 55	0.710	390	College	Asia	Custom Scale
56	(Altay & Saracalo, 2017)	Study 56	0.502	608	College	Asia	Custom Scale
57	(Cakici, 2018)	Study 57	0.731	218	College	Asia	Standardized Scale

58	(Kozikoğlu, 2019)	Study 58	0.617	229	College	Asia	Custom Scale
59	(Can, 2021)	Study 59	0.542	191	College	Asia	Custom Scale
60	(Diella & Ardiansyah, 2017)	Study 60	0.540	100	Senior High School	Asia	Custom Scale

Data analysis

Effect size. The data was summarized utilizing various tools, including Microsoft Excel, Jamovi 2.2.5, and OpenMEE software. These programs were employed to ascertain the effect size for individual studies, as well as for the overall and aggregate effect sizes. An overview of the data analysis process is depicted in Figure 2.

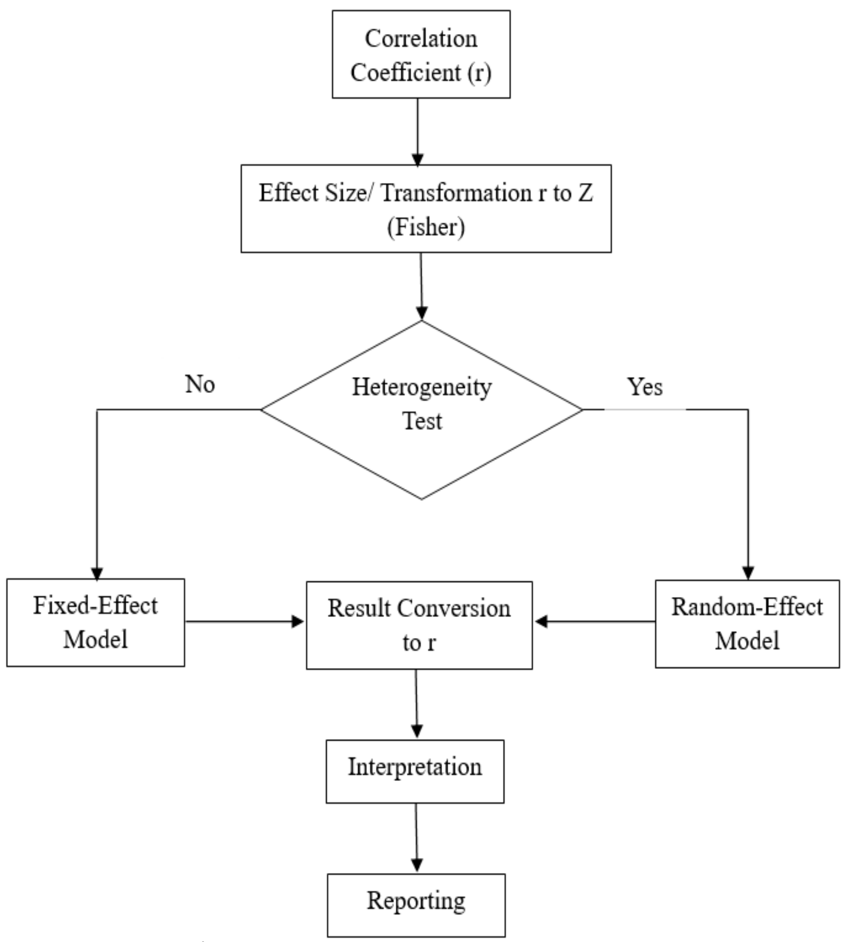

Figure 2. Schematic of correlation meta-analysis.

Cohen's effect size criteria, as outlined by Chamdani et al., (2022) in Table 2, classifies effect sizes according to values ranging from 0 to 1.

Table 1. Cohen's effect size criteria.

Value	**Criteria**

<0.1	Weak effect
<0.3	Modest effect
<0.5	Moderate effect
<0.8	Strong effect
≥0.8	Very strong effect

Evaluation of publication bias. This meta-analysis study used two approaches to explore publication bias, namely funnel plot and fail-safe N. Funnel plot was used to clearly present all effect sizes, and if the pattern formed was symmetrical, it indicated that there was no publication bias (Card, 2011). Fail-safe N was used to estimate the number of studies with insignificant results (unpublished data) needed, so that the average effect size became statistically insignificant (Rosenthal, 1979).

Findings and Discussion

Findings

Effect size. This study aimed to determine the correlation between metacognitive ability and critical-thinking skills. Based on the research of 60 studies, the data obtained are shown in Table 3.

Table 3. Data tabulation of the random-effects model.

No.	Study Name	*r*	*N*	Z	Vz	Sez	No.	Study Name	*R*	*N*	z	Vz	Sez
1	Study 1	0.260	103	0.266	0.010	0.100	31	Study 31	0.590	468	0.678	0.002	0.046
2	Study 2	0.350	147	0.365	0.007	0.083	32	Study 32	0.480	468	0.523	0.002	0.046
3	Study 3	0.460	2439	0.497	0.000	0.020	33	Study 33	0.190	21	0.192	0.056	0.236
4	Study 4	0.100	36	0.100	0.030	0.174	34	Study 34	0.300	25	0.310	0.045	0.213
5	Study 5	0.200	41	0.203	0.026	0.162	35	Study 35	0.740	23	0.950	0.050	0.224
6	Study 6	0.530	37	0.590	0.029	0.171	36	Study 36	0.770	190	1.020	0.005	0.073
7	Study 7	0.070	39	0.070	0.028	0.167	37	Study 37	0.209	111	0.212	0.009	0.096
8	Study 8	0.670	32	0.811	0.034	0.186	38	Study 38	0.122	111	0.123	0.009	0.096
9	Study 9	0.460	185	0.497	0.005	0.074	39	Study 39	0.063	111	0.063	0.009	0.096
10	Study 10	0.730	502	0.929	0.002	0.045	40	Study 40	0.372	111	0.391	0.009	0.096
11	Study 11	0.435	3000	0.466	0.000	0.018	41	Study 41	0.229	111	0.233	0.009	0.096
12	Study 12	0.444	3000	0.477	0.000	0.018	42	Study 42	0.140	111	0.141	0.009	0.096
13	Study 13	0.417	3000	0.444	0.000	0.018	43	Study 43	0.512	52	0.565	0.020	0.143
14	Study 14	0.441	3000	0.473	0.000	0.018	44	Study 44	0.533	50	0.594	0.021	0.146
15	Study 15	0.461	3000	0.499	0.000	0.018	45	Study 45	0.520	664	0.576	0.002	0.039
16	Study 16	0.756	33	0.987	0.033	0.183	46	Study 46	0.575	664	0.655	0.002	0.039
17	Study 17	0.852	33	1.263	0.033	0.183	47	Study 47	0.592	664	0.681	0.002	0.039
18	Study 18	0.723	37	0.914	0.029	0.171	48	Study 48	0.586	664	0.672	0.002	0.039
19	Study 19	0.845	137	1.238	0.007	0.086	49	Study 49	0.519	664	0.575	0.002	0.039
20	Study 20	0.720	137	0.908	0.007	0.086	50	Study 50	0.526	664	0.585	0.002	0.039
21	Study 21	0.590	450	0.678	0.002	0.047	51	Study 51	0.345	244	0.360	0.004	0.064

22	Study 22	0.593	230	0.682	0.004	0.066	52	Study 52	0.600	390	0.693	0.003	0.051
23	Study 23	0.591	220	0.679	0.005	0.068	53	Study 53	0.580	390	0.662	0.003	0.051
24	Study 24	0.629	78	0.740	0.013	0.115	54	Study 54	0.640	390	0.758	0.003	0.051
25	Study 25	0.905	109	1.499	0.009	0.097	55	Study 55	0.710	390	0.887	0.003	0.051
26	Study 26	0.626	109	0.735	0.009	0.097	56	Study 56	0.502	608	0.552	0.002	0.041
27	Study 27	0.949	109	1.822	0.009	0.097	57	Study 57	0.731	218	0.931	0.005	0.068
28	Study 28	0.828	109	1.182	0.009	0.097	58	Study 58	0.617	229	0.720	0.004	0.067
29	Study 29	0.790	468	1.071	0.002	0.046	59	Study 59	0.542	191	0.607	0.005	0.073
30	Study 30	0.770	468	1.020	0.002	0.046	60	Study 60	0.540	100	0.604	0.010	0.102

Before determining the summary effect (aggregate effect size), the heterogeneity test was first carried out. Table 4 displays the outcomes of this test.

Table 4. Heterogeneity test.

Tau	**Tau^2**	**I^2**	**H^2**	**Df**	**Q**	**P**
0.325	0.1058 (SE= 0.0212)	98.07%	51.827	59	1163.959	<0.001

These test findings indicated significant heterogeneity among the 60 effect sizes from the analyzed studies, evidenced by $Q = 1163.959$ with $p < 0.001$, τ^2 or $\tau > 0$, and $I^2 = 98.07\%$—nearly approaching 100%. Due to this heterogeneity, the Random-Effect Model was employed to establish the aggregate effect size. Table 5 showcases the results detailing the aggregate effect size.

Table 5. Random-effect model (k= 60).

	Estimate	**Se**	**Z**	**P**	**CI Lower Bound**	**CI Upper Bound**
Intercept	0.649	0.0439	14.7	<0.001	0.593	0.704

The analysis conducted via the random effect model revealed a noteworthy positive correlation between metacognitive ability and students' critical-thinking skills ($z = 14.7$; 95% CI [0.593; 0.704]). With a p-value of <0.001, the study's null hypothesis (Ho) is convincingly rejected. Consequently, it can be inferred that a significant relationship exists between metacognitive ability and critical-thinking skills, falling within the strong category ($r = 0.649$).

Additionally, the findings were visually presented using a forest plot, a helpful graphical method. This plot illustrated the estimated combined effect through plotted points at specific intervals, which aided in clearer comparisons between the studies. Notably, the effect sizes within the analyzed literature ranged from -0.27 to 2.01 according to the forest plot diagram.

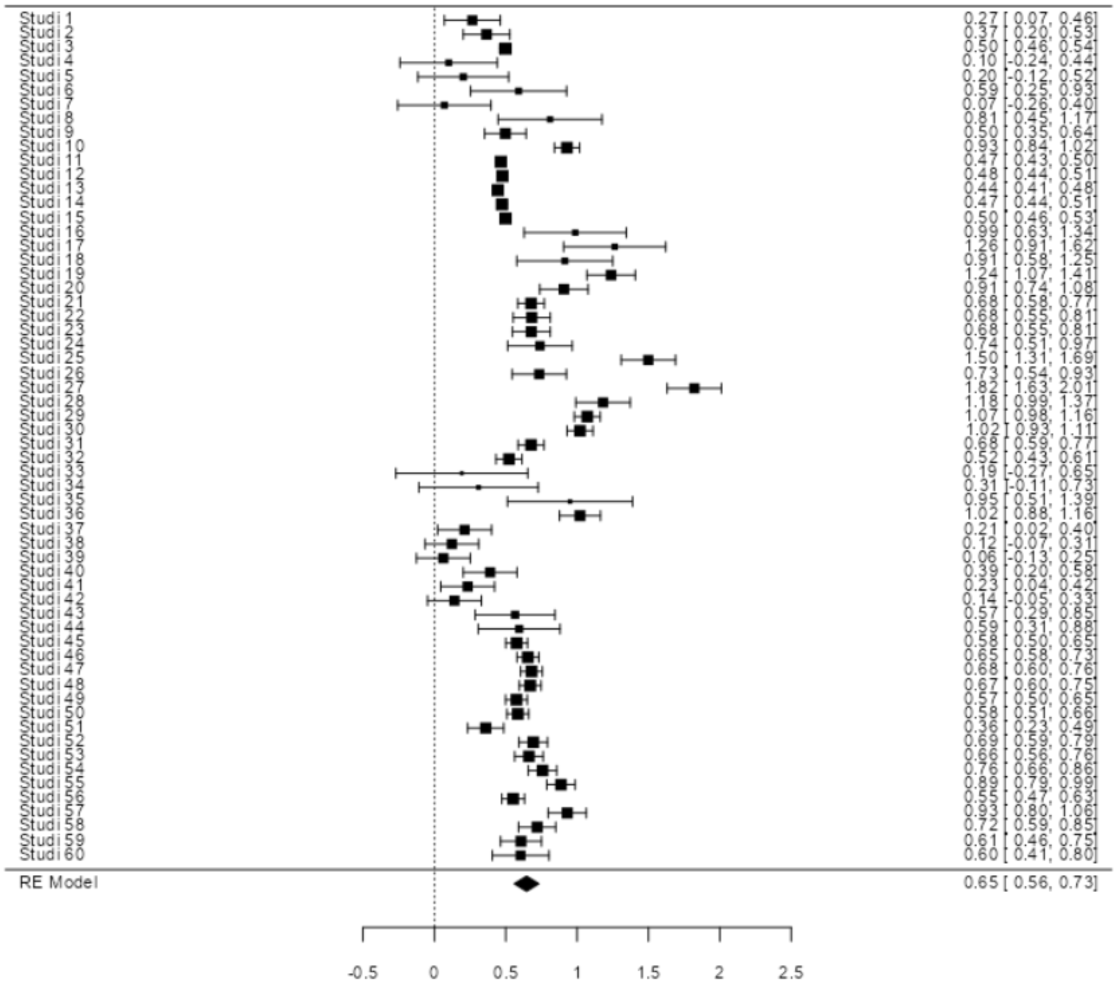

Figure 3. The forest plot analysis of the relationship between metacognition and critical-thinking skills.

Table 6 delineates the distribution of the 60 studies across various moderator variables, categorizing each study according to these specific classifications.

Table 6. Moderator variable.

Moderator variable	Category	*n* (%)
Publication type	Proceeding	3 (5)
	Journal	57 (95)
Location	Asia	49 (81.67)
	Non-Asia	11 (18.33)
Academic level	Elementary School	5 (8.33)
	Junior High School	8 (13.33)
	Senior High School	5 (8.33)
	College	42 (70)
Instrument Type	Custom Scale	22 (36.67)
	Standardized Scale	38 (63.33)

Table 7 illustrates the outcomes derived from the aggregate effect size analysis concerning the moderator variable, "Academic level." This table presents the synthesized results pertaining to how different academic levels influenced the aggregate effect size.

Table 7. Aggregate effect size of academic level.

Studies	Estimate	Lower bound	Upper bound	Std. error	p-Val
Subgroup College	0.654	0.592	0.717	0.032	< 0.001
Subgroup Senior High School	0.893	0.491	1.295	0.205	< 0.001
Subgroup Junior High School	0.380	0.218	0.542	0.083	< 0.001
Subgroup Elementary School	0.761	0.417	1.105	0.176	< 0.001
Overall	0.649	0.593	0.704	0.028	< 0.001

The presented results indicate a noteworthy correlation between metacognitive ability and critical-thinking skills across each academic level, as evidenced by p-values consistently below 0.001, or smaller than 0.05 for each academic tier. Additionally, the table demonstrates a strong correlation between metacognitive ability and critical-thinking skills at the college, senior-high-school, and elementary-school academic levels. At the junior-high-school level, the correlation between metacognition and critical-thinking skills registers as moderate.

The results of the aggregate effect size analysis using Asian and non-Asian location moderator variables can be seen in Table 8.

Table 8. Aggregate effect size location moderator variables.

Studies	Estimate	Lower bound	Upper bound	Std. error	p-Val
Subgroup Non Asia	0.375	0.253	0.497	0.062	< 0.001
Subgroup Asia	0.715	0.652	0.778	0.032	< 0.001
Overall	0.649	0.593	0.704	0.028	< 0.001

The presented results highlight a significant correlation between metacognitive ability and critical-thinking skills within both Asian and Non-Asian subgroups, evident from p-values consistently below 0.001, or smaller than 0.05 for each location. Moreover, the table illustrates a strong correlation between metacognition and critical-thinking skills in the Asian subgroup, while the correlation in the non-Asian subgroup is moderate.

Table 9 presents the outcomes obtained from the aggregate effect size analysis, based on the moderator variable "instrument type," distinguishing between Standardized Scale and Custom Scale. This table encapsulates the synthesized findings regarding how different types of instruments affected the aggregate effect size concerning metacognitive ability and critical-thinking skills.

Table 9. Aggregate effect size moderator variable of instrument type.

Studies	Estimate	Lower bound	Upper bound	Std. error	p-Val
Subgroup Standardized Scale	0.589	0.527	0.650	0.031	< 0.001
Subgroup Custom Scale	0.768	0.668	0.868	0.051	< 0.001
Overall	0.649	0.593	0.704	0.028	< 0.001

The presented results indicate a significant correlation between metacognitive ability and critical-thinking skills within both the Standardized Scale and Custom Scale subgroups, as evidenced by p-values below 0.001, or smaller than 0.05 for each instrument type. Additionally, the table demonstrates a strong correlation between metacognitive ability and critical-thinking skills in both the Standardized Scale and Custom Scale subgroups.

For the analysis based on the moderator variable, "publication type," involving journals and proceedings, the results can be observed in Table 10, which showcases the outcomes of the aggregate effect size analysis concerning how different publication types impact the relationship between metacognitive ability and critical-thinking skills.

Table 10. Aggregate effect size moderator variable of publication type.

Studies	Estimate	Lower bound	Upper bound	Std. error	p-Val
Subgroup Journal	0.653	0.597	0.710	0.029	< 0.001
Subgroup Proceeding	0.486	0.027	0.944	0.234	0.038
Overall	0.649	0.593	0.704	0.028	< 0.001

The outcomes presented above highlight a significant correlation between metacognition and critical-thinking skills within both the journal and proceedings subgroups, supported by p-values smaller than 0.05 for each subgroup. Moreover, the table illustrates a strong correlation between metacognitive ability and critical-thinking skills in the journal subgroup, while the correlation in the proceeding's subgroup registers as moderate.

Evaluation of publication bias. The funnel plot of the 60 studies indicated that the effect size plot spreads from negative to positive values (see Figure 4). The funnel plot also shows that the studies have varying standard errors. A symmetrical funnel plot in a linear regression test suggests that among the 60 studies analyzed, there was no significant asymmetry. This symmetry indicates that publication bias, which might skew results by favouring certain types of studies, does not seem to strongly influence the overall findings of this analysis.

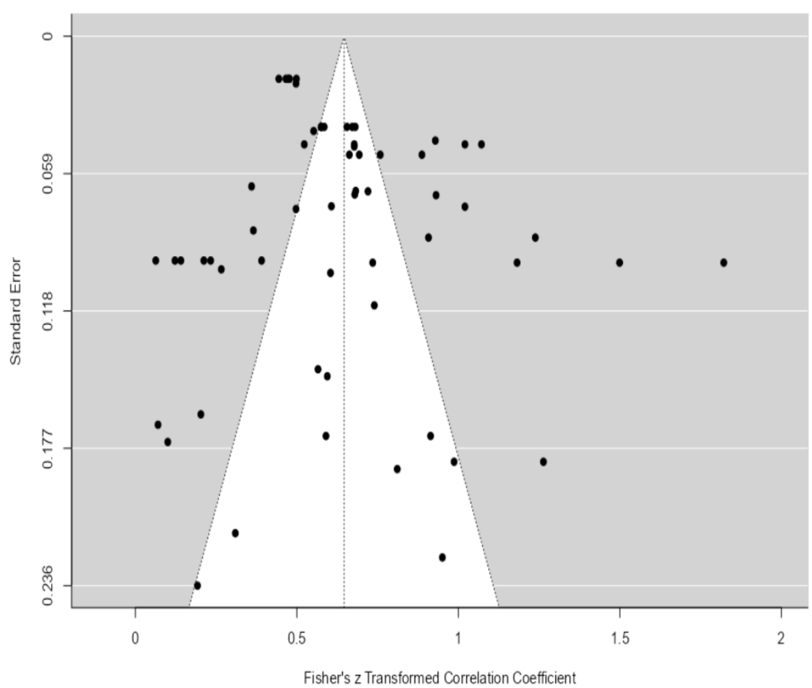

Figure 4. Funnel plot of metacognition effect size on critical-thinking skills.

The fail-safe N calculation, utilizing the Rosenthal approach, resulted in a value of 151125, with an observed significance level of <0.001, and a target significance level of 0.05. According to Rothstein's guideline (2008), a fail-safe N value exceeding 5K + 10 (where K represents the number of individual studies) suggests the absence of publication bias in the meta-analysis. In this study, with K = 60, the computed threshold is 310 (5(60) + 10 = 310). Comparing this threshold to the fail-safe N value of 151125, it is reasonable to conclude that there is not a significant publication bias problem in this analysis. Meanwhile, according to Begg and Mazumdar, a value of 0.025, which is smaller than the confidence interval of 0.783, indicated that there is no publication bias in this research (Begg & Mazumdar, 1994). Similarly, according to Egger, a value smaller than the confidence interval also implies the absence of publication bias (Lin & Chu, 2018). Additionally, Begg and Mazumdar's Rank Correlation and Egger's Regression both propose that there is no publication bias, if the funnel plot is symmetrical.

Tabel 11. Publication bias assessment.

Test name	value	P
Fail-Safe N	151125	<.001
Begg and Mazumdar Rank Correlation	0.025	0.783
Egger's Regression	-0.286	0.775

Discussion

According to the data analysis outcomes, the research sample indicates a meaningful positive correlation between metacognition and critical thinking skills (p-value <0.05). As students demonstrate greater proficiency in utilizing metacognitive knowledge, orchestrating and overseeing their learning processes, rectifying errors, and evaluating their learning experiences, their critical thinking skills tend to improve (Maoulida et al., 2023b; Pamungkas et al., 2019; Sukarno & Musyafa, 2021).

Additionally, the effect size analysis reveals that the correlation between metacognition and critical thinking skills falls within the strong category according to Cohen's criteria (r = 0.649). This substantial correlation underscores the robust relationship between metacognition and the development of critical-thinking abilities. Practicing students' metacognition skills is considered effective in improving critical-thinking skills. Therefore, teachers' efforts in improving students' critical-thinking skills should not only focus on the use of learning models and teaching materials. Indeed, while highlighting the significance of metacognition skills, it is equally crucial to emphasize and consider students' foundational abilities. These fundamental skills form the bedrock upon which higher-order cognitive functions, like metacognition and critical thinking, are built. Therefore, acknowledging and nurturing these foundational abilities alongside metacognition skills is essential for a comprehensive approach to student development (Nusantari et al., 2021). The results obtained from this meta-analysis align with previous studies examining the correlation between metacognition ability and critical thinking skills. This consistency across multiple studies reinforces the understanding of the strong relationship between these two constructs, emphasizing the reliability and robustness of their association in academic contexts (Guven & Cakir, 2019; Kozikoğlu, 2019; Son, 2020).

Metacognition, indeed, holds a crucial role in fostering the development of critical thinking. It empowers individuals to become conscious of their thinking processes, enabling them to enhance these processes for better knowledge acquisition. Critical thinking thrives on well-operating metacognitive mechanisms that facilitate awareness of the cognitive processes, actions, and emotions involved. This awareness allows individuals to recognize inadequacies, understand areas for improvement, and subsequently refine their thinking strategies to achieve better outcomes (Rivas et al., 2022).

Furthermore, the moderator variables were analyzed. When viewed from the academic level, metacognition has a significant relationship with critical-thinking skills at each academic level. This is evidenced by the p-value at each academic level (p-value <0.05). The analysis results show that the relationship between metacognition and critical thinking skills is at a strong level at the college and elementary school levels. This result is consistent with several studies on metacognition and critical thinking skills (Amin et al., 2020; Guven & Cakir, 2019; Son, 2020; Tuaputty et al., 2021). This finding contradicts research (Leasa, 2018; Lehmann, 2022; Marquès Puig et al., 2022) which found that the relationship between metacognition ability and critical-thinking skills was at a low level. However, results obtained at the junior-high-school academic level showed that metacognition ability and critical-thinking skills had a weak relationship ($r=0.380$), which is consistent with previous research (Kurt & Sezek, 2022; Popova et al., 2022).

In terms of the type of instrument used, it shows that metacognitive ability and critical-thinking skills have a significant relationship. There is no difference in the relationship between those who use standardized instruments and instruments developed by researchers. These findings are consistent with other findings (Ghasemi & Dowlatabadi, 2018; Guven & Cakir, 2019) which state that metacognition and critical-thinking skills have a significant relationship using standardized instruments and using researcher-developed instruments. Analysis on other moderator variables also shows that metacognition and critical-thinking skills have a significant relationship both from the continent variable (Asian or non-Asian) and the publication type variable (journal or proceedings).

Moreover, when exploring other moderator variables, like continent (Asian or non-Asian) and publication type (journal or proceedings), the analysis affirms a consistent and significant relationship between metacognition and critical-thinking skills across these different categories. This consistency echoes the robustness of the relationship between these constructs, regardless of geographical locations or publication sources

Conclusion and Recommendations

The limitation of this study is the reliance solely on Scopus indexed publications in English, excluding studies published in other languages, potentially impacting the comprehensiveness and inclusivity of the findings, and missing out on valuable insights from studies published in non-English languages. From the presented results and discussions, this research identified the significant relationship between metacognitive ability and critical-thinking skills. The effect size derived from analyzing 60 heterogeneous studies demonstrated a robust and positive correlation. Moreover, the absence of publication bias signified that the reviewed publications accurately represent the actual scenario. The diverse characteristics of these publications specified samples drawn from various scientific fields. It is recommended that future researchers explore whether similar themes are evident within specific academic disciplines, such as mathematics, physics, geography, economics, or other domains, to comprehensively understand the relationship between metacognitive abilities and critical-thinking skills.

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