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Cognitive style and Students' academic achievement: a meta-analysis

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This study investigates the relationship between field independence and dependence on cognitive style and student academic achievement. A meta-analysis was conducted on 42 studies related to this topic. The findings reveal a significant positive correlation between field independence and dependence on cognitive style and academic achievement among primary and middle school students ($r = 0.308$, $p < 0.01$). Subgroup analyses further indicate that factors such as the cognitive style measurement instrument ($Q_B = 111.347$, $p < 0.01$), subject area ($Q_B = 71.652$, $p < 0.01$), and academic achievement type ($Q_B = 35.083$, $p < 0.01$) significantly moderate this relationship. However, gender ($Q_B = 2.771$, $p > 0.01$) and educational stage ($Q_B = 5.952$, $p > 0.01$) do not appear to have a significant impact on the effect size. These findings highlight the importance of considering methodological and contextual factors when examining the influence of cognitive style on academic performance. Future research should explore potential mechanisms underlying these relationships to inform more effective educational strategies.

KEYWORDS

cognitive style, field independence, field dependence, academic achievement, meta-analysis

1 Introduction

In the field of education, cognitive style is recognized as a significant psychological factor influencing student learning (Kholid et al., 2020). Previous research suggests that students' diverse cognitive styles can shape their interests and preferences, ultimately affecting their academic achievement. Cognitive style refers to a typical or habitual pattern of behavior that emerges when students perceive, memorize, process information, and engage in thinking (Allport and Harrington, 1938). Witkin et al. (1971, 1977) classified cognitive style into two categories: field independence and field dependence, distinguishing how students perceive and process information. Field-independent students tend to focus on details, process information analytically and abstractly, and rely on internal cues when making judgments. Their perception and cognitive processes are relatively independent of the surrounding environment, allowing them to maintain a high degree of autonomy and remain less influenced by external factors. In contrast, field-dependent students rely more on external cues for information processing. Their attitudes and self-perceptions are

more susceptible to the influence of others, particularly authority figures. They excel in interpreting social cues, such as spoken language and facial expressions, and are more adept at perceiving and memorizing information within a social context (Chen et al., 2016; Wang, 2014; Witkin et al., 1971, 1977).

Numerous studies have explored the relationship between students' cognitive styles and their academic achievement; however, findings remain inconclusive. Academic achievement reflects the level of knowledge and skills students acquire through the learning process, often measured by examination results that serve as indicators of their learning abilities. Some researchers argue that cognitive style exerts a significant positive influence on academic performance across various disciplines, including Mathematics (Donnarumma et al., 1980; Mousavi et al., 2012; Picciarelli et al., 1995), Physics (Ates and Cataloglu, 2007; Cataloglu and Ates, 2014), Chemistry (Bahar and Hansell, 2000; Danili and Reid, 2006), and Science (Gennaro et al., 1992). Specifically, research suggests that cognitive style, particularly the distinction between field independence and dependence, serves as a critical predictor of students' examination scores and is strongly correlated with their overall academic achievement. Additionally, several studies have examined the impact of cognitive style on academic performance across multiple disciplines among middle school students, emphasizing its role as a key factor influencing overall student success (Niaz et al., 2000; Paramo and Tinajero, 1990; Tinajero and Paramo, 1997). Furthermore, investigations into the effects of cognitive style on students' problem-solving and image perception abilities indicate that cognitive style significantly influences students' capacity to interpret visual information (Mshelua and Lapidus, 1990; Nasser and Carifio, 1993).

Recent studies have suggested that there is no significant correlation between students' cognitive style—specifically, field independence and dependence—and their academic achievement. For instance, Soureshjani and Safikhani (2012) found that students' fluency in English had no measurable impact on their cognitive style. Similarly, in examining the relationship between cognitive style and mathematical performance, Adegoke (2011) and Vega-Vaca and Hederich-Martnez, 2015 reported no statistically significant effect of cognitive style on students' mathematics achievement. Tinajero and Paramo (1997) further argued that cognitive style, as assessed by the Pole Test, was not a significant source of variance in students' academic performance. Moreover, Kamaruddin et al. (2004) identified a negative correlation between students' field independence and dependence cognitive styles and their achievement in Chemistry.

There are still divergent views on the relationship between students' field independence and dependence cognitive style and academic achievement. While some scholars have attempted to conduct meta-analyses on this topic, existing studies have not provided conclusive findings. For example, Garlinger and Frank (1986) conducted a micro meta-analysis examining the relationship between teachers and students paired cognitive styles and students' academic performance. Their findings suggested that students who shared a similar cognitive style with their teachers (in terms of field independence or dependence) tended to achieve slightly higher academic outcomes. However, this study also indicated that teachers' cognitive styles may influence students' cognitive styles, thereby indirectly affecting their academic performance.

Notably, a review of the existing literature reveals that, to date, no meta-analysis has focused exclusively on the relationship between students' cognitive style (field independence and dependence) and their academic achievement. To address this gap, the present study aims to conduct a comprehensive meta-analysis to establish a more consistent understanding of this relationship. By synthesizing previous research, this study seeks to contribute to the advancement of the field and provide insights for future educational research.

After analyzing a substantial number of articles and meta-analytic literatures on cognitive styles and academic achievement, we identified several potential moderating variables that may affect the effect sizes and conclusions of the studies. To systematically and scientifically examine the impact of these potential moderating variables and evaluate the relationship between field independence and dependence cognitive style and students' academic achievement, we conducted subgroup analysis on variables such as students' gender, educational stage, cognitive style measurement instrument, subject area and type of academic achievement. The selection of these key moderating variables was informed by a comprehensive literature review and aligns with the central theme of this study. Moreover, these factors have been considered in previous meta-analyses with similar focuses (Alegre Ansuátegui et al., 2018; Garlinger and Frank, 1986; Lazonder and Harmsen, 2016; Shen et al., 2020). These will be further analyzed and discussed in subsequent modules.

This study aims to examine the following two research questions based on meta-analysis:

- (1) What is the relationship between field independence and dependence cognitive style and academic achievement, among students in primary and secondary education?
- (2) Will such a relationship be affected by students' gender, educational stage, cognitive style measurement instrument, field of study, academic achievement level or any other factors?

2 Methods

This study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, a standardized and widely recognized framework for conducting systematic reviews and meta-analyses. The PRISMA checklist was rigorously applied throughout the research process to enhance the quality, transparency, and replicability of the review (Page et al., 2021).

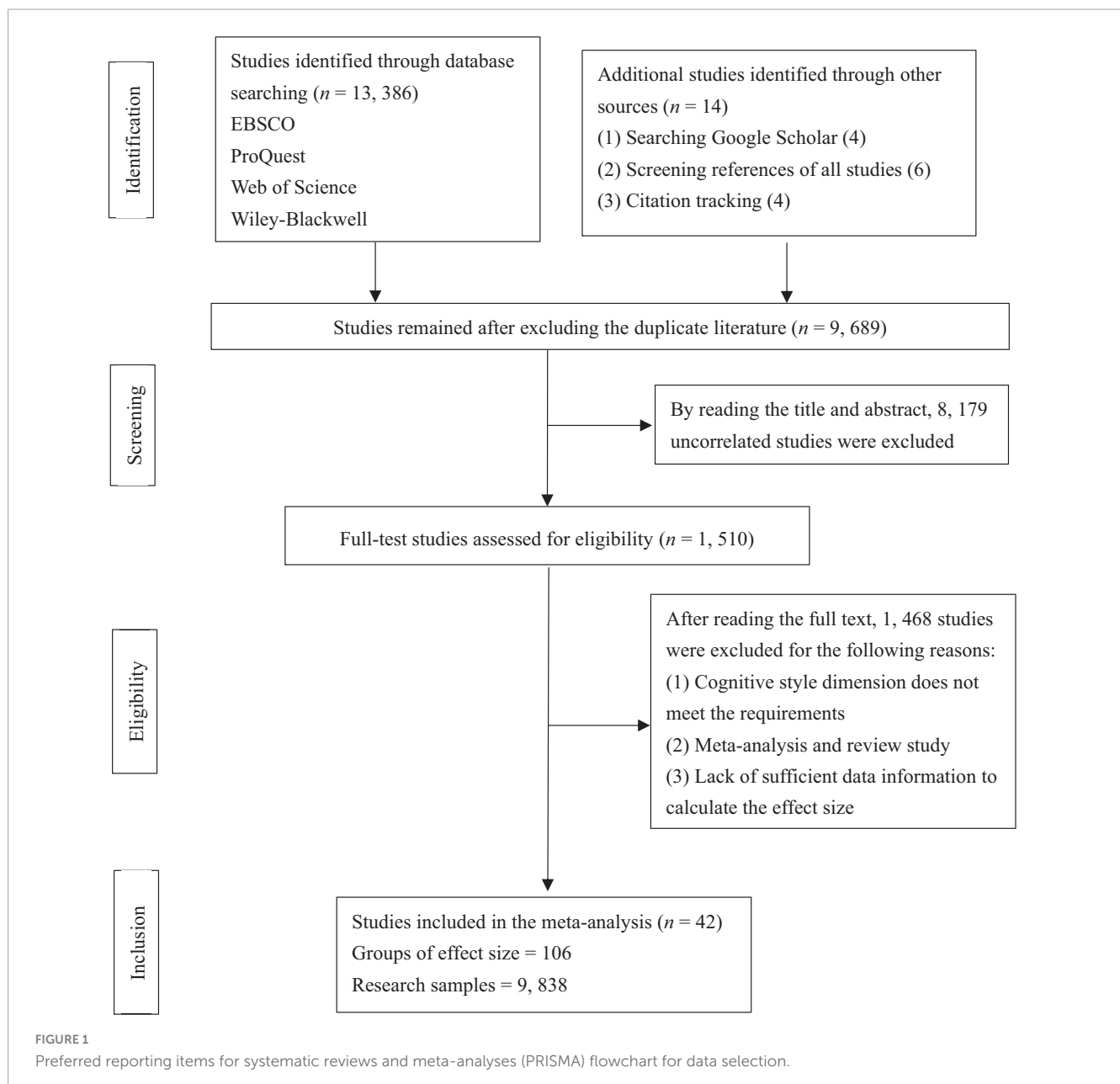
2.1 Research strategies

A systematic search of the international literature was conducted in the following electronic databases: EBSCOhost, ProQuest Education Journals, Web of Science, Wiley-Blackwell, and Google Scholar. The language was limited to English, and the time of publication lasted between 1 January 2000 and 1 January 2024. The search strategy used Boolean combinations of the following keywords: ("cognitive style" OR "field independence"

OR “field dependence”) AND (“achievement” OR “academic achievement” OR “performance” OR “learn” OR “study”). Reference lists of the selected articles were screened and the gray literature (e.g., reports, unpublished research) were carefully searched. A total of 13,400 articles were obtained from the entire search procedure (Figure 1).

Relevant literature was selected for this study according to the following inclusion and exclusion criteria:

1. We included literature published in English and excluded literature published in other languages
2. We included literature that discusses the relationship between students' cognitive style and academic achievement, and excluded literature that only discusses students' cognitive style or academic achievement, while excluding the literature that discusses other issues
3. We included literature that discusses the field independence and dependence cognitive style, and excluded literature that does not analyze the field independence and dependence cognitive style
4. We included the studies in which academic scores and indicative of the student's academic achievement, or skill achievement obtained from various examinations, tests or scales, while excluding the studies that do not present students' examination scores or skills relevant to their achievements
5. For empirical research purposes, we included the studies that provide sufficient statistical evidence for calculating the effect size of meta-analysis, such as the total number of samples (N), mean (M), standard deviation (SD), or t -value, F -value, effect size d and η^2 , etc., and excluded the studies that are merely theoretical or constitute literature reviews, do not



report experimental results, show incomplete data, or the full source texts are not available

6. We included the studies in which participants are students in primary or secondary education (including junior middle school and senior middle school), and excluded the studies in which participants are students at any other educational stage, such as preschool education or higher education
7. The same literature would only be selected once

Based on the inclusion and exclusion criteria described above, carefully screen the full texts of the remaining papers and conduct a qualification assessment. There were 42 studies that met the criteria for meta-analysis and were included in the study, and 106 groups of effect size and 838 research samples were obtained (Figure 1).

2.2 Coding procedure

Two researchers received unified training first and then extracted the literature data and coded them in detail. The literature was coded based on the following criteria: literature information (author, year of publication), population characteristics (including sample size, gender and education stage), cognitive style measurement instrument, types of academic achievement and comprehensive effect sizes. When differences in coding were observed (for example, the componential division of academic achievement involved in the literature and the description of samples), the two coders would discuss and synthesize the opinions of a third party to achieve a consistent view. Finally, the two coders obtained a high degree of consistency (87.9%) which could ensure coding accuracy (see Table 1 for specific coding).

2.3 Calculation of effect size

In this meta-analysis, the Pearson correlation coefficient (r) was adopted as the effect size to reflect the relationship between students' cognitive style and academic achievement. For the literature that did not provide a correlation coefficient, but instead reported t -value, F -value, effect size d , η^2 , etc., these values would be transformed into r -values for analysis following the statistical test. These formulas can be found in the studies of Rosenthal (1986) and Schwarzer (1989).

According to Cohen (1988), an effect size r smaller than "0.20" is deemed small, that between "0.21" and "0.79" is considered medium, and that larger than "0.80" is regarded as large.

2.4 Statistical analysis

In this study, the Comprehensive Meta Analysis 3.0 (CMA 3.0) software was used for data analysis. There are two types of meta-analysis models, the random-effects model and the fixed-effects model. The fixed-effects model is the basis of all studies, because there is only a single real effect quantity in the hypothesis study, while the random-effects model allows the real effect quantity that fluctuates in the overall distribution of the study. Therefore, the results using the random-effects model are more suitable for

a series of scenarios than for those that are using the fixed-effects model (Borenstein et al., 2021). This study aims to explore the moderating effects of students' gender and education level, cognitive style measurement tools, subject areas, and academic achievement levels on the relationship between cognitive style (specifically field independence and dependence) and academic achievements.

In addition, the choice of effects model can also refer to the significance of the effect quantity. When the effect size is significant, the random effects model is employed. In that regard, when the effect size is not significant, the fixed-effects model is adopted. This study used the heterogeneity test (Q -test and I^2 statistics) to represent the possible heterogeneity from an empirical perspective. Additionally, a heterogeneity test is required to form a decision on whether each research result can represent the sample estimation of the overall effect size. Conventionally, if the test results show that the effect size is homogeneous (not significant) ($p > 0.05$, $I^2 \leq 50\%$), the fixed-effects model is employed. On this point, if the effect size is heterogeneous (significant) ($p \leq 0.05$, $I^2 > 50\%$), the random-effects model is adopted. Statistics Q and heterogeneity statistics I^2 are complementary, and 25%, 50% and 75% can represent low, medium and high heterogeneity, respectively (Higgins et al., 2003).

Furthermore, bias problems may be yielded in meta-analysis, of which publication bias is the most common type. Publication bias suggests that in the process of collecting data, researchers may only collect data from published literature without considering including unpublished literature, which will lead to a higher effect size of meta-analysis than the real value (Kuppens et al., 2013). To minimize such bias, this study conducted publication bias tests by funnel plot, Egger's linear regression, Begg and Mazumdar's rank correlation method and Fail-safe Number.

3 Results

3.1 Summary of the characteristics of the literature

A total number of 106 groups of data on the relationship between cognitive style and academic achievement were obtained from the 42 studies that were included in this meta-analysis. The data were combined into 50 comprehensive effect sizes according to the research content (Table 1). Additionally, 4 studies were dissertation theses, while 38 of them were journal articles, while 6 kinds of cognitive style measuring instruments were used in the study, namely Children's Embedded Figures Test (CEFT), Group Embedded Figures Test (GEFT), Embedded Figures Test (EFT), Goodenough-Harris Drawing Test: Draw-A-Person Test (DAPT), Cognitive Style Test (CST), Find-A-Shape Puzzle (FASP). In the present study, academic achievement was divided into two types: achievement score and achievement skill.

3.2 Analysis of overall effect size

Table 2 presents the heterogeneity test results of the correlation coefficient between students' cognitive style and

TABLE 1 Characteristics of 42 studies on the relationship between students’ cognitive style and academic achievement in the meta-analysis.

References	Sample sizes	Sex	Education stage	Measurment tool	Academic achievement type	Comprehensive effect sizes
Niaz et al., 2000	141	Mix	Secondary education	GEFT	Academic performance ^a : Spanish, English, geography, biology, chemistry, earth science, mathematics and physics	0.173
Daniels and Moore, 2000	122	Mix	Secondary education	GEFT	Problem-solving questions scores ^b	0.309
Kirk, 2000 (1)	84	Mix	Secondary education	GEFT	Achievement in the chemistry classroom ^a : academic achievement, laboratory achievement, problem-solving achievement	0.360
Kirk, 2000 (2)	43	Male	Secondary education	GEFT	Achievement in the chemistry classroom ^a : academic achievement, laboratory achievement, problem-solving achievement	0.503
Kirk, 2000 (3)	41	Female	Secondary education	GEFT	Achievement in the chemistry classroom ^a : academic achievement, laboratory achievement, problem-solving achievement	0.273
Bahar and Hansell, 2000	101	Mix	Secondary education	GEFT	Performance of the grid-type of questions and of word association tests in biological concepts ^a	0.145
Pekljaj, 2003 (1)	164	Mix	Primary education	GEFT	Mathematics achievement test scores ^a	0.206
Pekljaj, 2003 (2)	150	Mix	Primary education	GEFT	Slovenian achievement test scores ^a	0.217
Kamaruddin et al., 2004	163	Mix	Secondary education	GEFT	Chemistry achievement ^a	−0.048
Kang et al., 2005	159	Mix	Secondary education	FASP	Conceptual change in students’ science concept learning ^a	0.334
Danili and Reid, 2006	476	Mix	Secondary education	GEFT	Chemistry tests ^a : atomic structure, classification of matter, solubility; the periodic table and chemical bonds; mole concept; acids, alkalis, pH, neutralization; solutions	0.269
Guisande et al., 2007	149	Mix	Primary education	CEFT	Attentional functioning performance scores ^b : digits forward and digits backward, digit symbol subtest, and the visual search and attention test	0.301
Alamolhodaiei, 2009	161	Female	Secondary education	GEFT	Mathematics exams achievement ^a	0.213
Homayouni et al., 2009 (1)	119	Mix	Secondary education	GEFT	English achievement ^a	0.200
Homayouni et al., 2009 (2)	56	Male	Secondary education	GEFT	English achievement ^a	0.350
Homayouni et al., 2009 (3)	63	Female	Secondary education	GEFT	English achievement ^a	0.090

(Continued)

TABLE 1 (Continued)

References	Sample sizes	Sex	Education stage	Measurement tool	Academic achievement type	Comprehensive effect sizes
Abdolahi et al., 2009	143	Mix	Secondary education	GEFT	Calculus word problem exams ^b	0.358
Tsitsipis et al., 2010	329	Mix	Secondary education	GEFT	Students' understanding of the structure of matter and its changes of state such as melting, evaporation, boiling, and condensation ^b	0.330
Akhtar, 2010	511	Mix	Secondary education	GEFT	Achievement in the subject of science ^a	0.350
Arisi, 2011	192	Mix	Secondary education	CST	Academic achievement in social studies ^a	0.455
Adegoke, 2011	270	Mix	Secondary education	GEFT	Mathematics achievement ^a	0.090
Nicolaou and Xistouri, 2011	94	Mix	Primary education	GEFT	Problem-posing ability in mathematics ^b	0.449
Afkhami et al., 2012	281	Mix	Primary education/secondary education	GEFT	Students' mathematical literacy (ML) in different level (K5, K8, K11) ^b	0.347
Cakan, 2012	156	Mix	Secondary education	GEFT	Science achievement of the students on the unit of "Atom and atomic structure" ^a : Multiple choice test Essay exam Short answer questions	0.536
Guisande et al., 2012	149	Mix	Primary education	CEFT	Attentional functioning performance ^b : digits forward, digits backward, digit symbol subtest and visual search and attention test; visuospatial abilities performance (block design, rey-osterrieth complex figure)	0.422
Hong et al., 2012 (1)	100	Mix	Secondary education	GEFT	Digital jigsaw puzzles scores ^b : Taiwan and Europe map	0.240
Hong et al., 2012 (2)	110	Mix	Secondary education	GEFT	Digital jigsaw puzzles scores ^b : Taiwan and Europe map	0.320
Mousavi et al., 2012	183	Female	Secondary education	GEFT	Mathematics exam achievement ^a	0.580
Jantan, 2014	150	Mix	Primary education	GEFT	Mathematic achievement ^a	0.477
Kypriaos et al., 2014	374	Mix	Secondary education	GEFT	Understanding of the chemical change ^a : understanding of the substances structure (structure understanding); recognition of the substances change (change recognition); interpretation of the substances changes (interpretations)	0.183
Su et al., 2014	45	Mix	Primary education	GEFT	Marine education academic achievement ^a	0.243
Mundra, 2014	423	Mix	Primary education	GEFT	Classroom achievement in social studies, English, math, hindi and science ^a	0.395

(Continued)

TABLE 1 (Continued)

References	Sample sizes	Sex	Education stage	Measurem tool	Academic achievement type	Comprehensive effect sizes
Perry, 2014	80	Mix	Secondary education	GEFT	Music performance skills ^b	0.043
Vega-Vaca and Hederich-Martnez, 2015	76	Mix	Primary education	EFT	Academic achievement ^{a+b} : test knowing mathematics and Spanish	0.238
Karaçam and Baran, 2015	295	Mix	Secondary education	GEFT	Conceptual understandings about direct current circuit concepts ^b : direct current resistive electric circuit test	0.370
Nozari and Siamian, 2015	305	Mix	Secondary education	GEFT	English text reading comprehension, learning English as a foreign language, academic achievement ^{a+b}	0.314
Khodadady et al., 2016	658	Mix	Primary education	DAPT	Achievement in English as a foreign language ^a	0.088
Huertas et al., 2017	104	Mix	Secondary education	EFT	Learning achievements in chemistry ^a	0.789
Mefoh et al., 2017	240	Mix	Secondary education	GEFT	Problem-solving ability ^b	0.249
Ahiauzu, 2017	1048	Mix	Secondary education	GEFT	Junior WAEC academic achievement ^a	0.062
Sharma, 2018	64	Mix	Secondary education	GEFT	Academic achievement using multimedia and traditional instructional strategies ^a	0.733
Lei et al., 2020 (1)	89	Mix	Secondary education	EFT	Creative performance ^b : fluency, flexibility, originality	0.311
Lei et al., 2020 (2)	92	Mix	Secondary education	EFT	Creative performance ^b : fluency, flexibility, originality	0.196
Ceran and Ates, 2020	80	Mix	Secondary education	GEFT	Conceptual understanding levels in science ^b	0.413
Surur et al., 2020	120	Mix	Secondary education	GEFT	Problem-solving abilities ^b	0.334
Sulaiman et al., 2022	62	Mix	Secondary education	GEFT	Genetic achievement ^a	0.124
Sianturi et al., 2022	21	Mix	Secondary education	GEFT	Mathematics academic achievement ^a	0.375
Dzulfikar and Herman, 2023	182	Mix	Secondary education	GEFT	Mathematical problem-solving skills ^b	0.295
Sahin and Ates, 2023 (1)	377	Male	Secondary education	GEFT	Logical thinking and mental rotation ability ^b	0.301
Sahin and Ates, 2023 (2)	446	Female	Secondary education	GEFT	Logical thinking and mental rotation ability ^b	0.367

Cognitive style measurement instrument: GEFT, Group Embedded Figures Test; CEFT, Children's Embedded Figures Test; EFT, Embedded Figures Test; DAPT, Goodenough Harris Drawing Test; Draw-A-Person test; CST, Cognitive Style Test; FASP, Find-A-Shape Puzzle.
^aAcademic achievement score, ^bAcademic achievement skill.

TABLE 2 Results of effect size heterogeneity test (Q statistics).

Random effects	k	Heterogeneity				T^2			
		Q -value	df (Q)	P -value	I^2	T^2	SE	Variance	T
	106	583.490	105	0.000	82.005	0.024	0.005	0.000	0.156

k was the number of effect sizes. SE, Standard Error.

academic achievement. The Q -value is 583.490, at a significant level ($p < 0.01$), indicating that there was heterogeneity among each effect size. The measure of I^2 is 82.005 which indicates that in the study of the relationship between cognitive style and academic achievement, 82.005% of the observed variation was caused by the true deviation of effect size, while only 17.995% of the observed variation was due to random error. The I^2 dividing points for distinguishing high, moderate and low heterogeneity were 75%, 50% and 25%, respectively. An I^2 value of 82.785 revealed that each effect size in the study was high in heterogeneity. The value of Tau^2 was “0.024,” denoting that when weighting each study under random-effects model, 2.4% of the inter-study variation could be used for weight calculation. Statistical analysis showed that there was heterogeneity in each effect size. Therefore, the random-effects model analysis method was employed in the study.

Table 3 shows the overall correlation effect size between students' cognitive style and academic achievement. There were 106 effect sizes. The overall correlation effect size r between cognitive style and academic achievement was “0.308,” indicating a medium correlation, with a 95% confidence interval (CI) ranging from 0.277 to 0.339, $z = 18.167$, reaching a significant level ($p < 0.01$). For the 95% CI [0.277, 0.339] in the context of students' cognitive style and academic achievement: it means we're 95% confident the true correlation between the two in the student population lies here. Since both bounds are above 0 (coupled with $p < 0.01$), it confirms a significant positive link. Notably, the entire interval stays within the medium correlation range, solidifying that the association between students' cognitive style and academic achievement is indeed of medium strength. The narrow interval also reflects a precise estimate of this correlation.

3.3 Analysis of subgroup effect size

Subgroup analysis aims to investigate the influence of certain variables on effect size. We used random-effects model to test and then summarized the results of the subgroup analysis (see Table 4). The subgroup analysis of this study mainly focused on the impact of factors, such as students' gender, educational stage, cognitive style measurement instrument, subject area and type of academic achievement. The purpose of it was to study more comprehensively, systematically and scientifically, and evaluate the relationship between field independence and dependence cognitive style and students' academic achievement. These factors are considered in the meta-analysis research related to students' cognitive style or academic achievement (Alegre Ansuátegui et al., 2018; Garlinger and Frank, 1986; Lazonder and Harmsen, 2016; Shen et al., 2020).

The results showed that cognitive style measurement instrument ($Q_B = 111.347$, $p < 0.01$), subject area ($Q_B = 71.652$, $p < 0.01$) and academic achievement level ($Q_B = 35.083$, $p < 0.01$) significantly affected the relationship between students' cognitive style and academic achievement. Nevertheless, students' gender ($Q_B = 2.771$, $p > 0.01$) and educational level ($Q_B = 5.952$, $p > 0.01$) had no significant impact on the effect size of the relationship between students' cognitive style and academic achievement.

This study used six kinds of instruments for measuring cognitive style, namely GEFT ($k = 83$, $p = 0.000$), CEFT ($k = 9$, $p = 0.000$), EFT ($k = 9$, $p = 0.000$), DAPT ($k = 3$, $p = 0.000$), CST ($k = 1$, $p = 0.000$) and FASP ($k = 1$, $p = 0.000$) (k was the number of effect sizes). Group Embedded Figures Test (GEFT) is a paper-and-pencil performance test invented by Witkin and co-workers, and is used to evaluate the participant's field independence and dependence cognitive style (Witkin et al., 1971; Witkin et al., 1977). It has become a widely used instrument. The GEFT requires the test-takers to find simple geometric figures in some complex figures. It consists of three parts. The questions in the first part are used only for familiarizing the test-takers with the question type, and the score in the first part is not included in the final test score. The final test score is the sum of the scores of the second and the third parts. A test-taker whose final score is higher than the score calculated by subtracting a quarter of standard deviation from the average score is regarded as field independent, while a test-taker whose final score is lower than the score calculated by subtracting a quarter of standard deviation from the average score is considered field dependent (Bahar, 2003). Embedded Figures Test (EFT) is an evaluation instrument similar to GEFT. Children's Embedded Figures Test (CEFT) is a kind of test paper adapted from EFT to evaluate the cognitive style of test-takers, and seems to be more suitable for students under the age of 12 (Witkin et al., 1971). Draw-A-Person Test (DAPT) is also an effective cognitive style measurement instrument which includes Draw-A-Man Test (DAMT) and Draw-A-Woman Test (DAWT) (Rouse, 1964). In the application of DAPT, participants would be asked to draw a complete image of a man in five minutes without eraser or ruler. After that, they would be asked to draw a complete image of a woman again which is also time-limited (Kniel and Kniel, 2008). Cognitive Style Test (CST) is another instrument used to estimate students' type of cognitive style. Find-A-Shape Puzzle (FASP) is a cognitive measurement instrument similar to GEFT, which also requires students to find simple geometric figures hidden in complex figures within a time limit (Linn and Kyllonen, 1981). The above six measurement instruments can effectively evaluate students' field independence and dependence cognitive style.

With regard to the selected disciplines of the study, the field of Science was the largest sample ($k = 47$, $p = 0.000$), followed

TABLE 3 Overall effect size of correlation coefficient between cognitive style and academic achievement among students.

Model	<i>k</i>	Number of samples	Effect size and 95% interval			Test of null (2-tail)	
			Point estimate	Lower limit	Upper limit	Z-value	P-value
Random effects	106	9838	0.308	0.277	0.339	18.167	0.000

k was the number of effect sizes.

by those in the field of Language ($k = 15$, $p = 0.000$) such as English, Spanish, Slovenian, etc. The number of studies in the field of Mathematics ($k = 16$, $p = 0.000$) was almost equivalent to the number of studies in the field of Psychology ($k = 13$, $p = 0.000$). The field of Music ($k = 1$, $p = 0.706$) was also involved but its impact was not significant. Those non-subject areas were categorized into “other” fields ($k = 14$, $p = 0.000$) (k was the number of effect sizes). Furthermore, the results also showed that all the studies were positively correlated with the effect size. With the exception of the field of Music which had no significant impact on the effect size, all other variables had significant differences on the effect size.

3.4 Control of publication bias

The present study also tested the publication bias of the investigated literature. First, the publication bias of the meta-analysis was checked through the funnel plot (Light and Pillemer, 1984) (see Figure 2). The funnel plot showed that most of the studies that involved the relationship between students’ cognitive style and academic achievement were located at the top of the funnel, and more rarely at the bottom. As the funnel was inverted and symmetrical, the possibility of publication bias in this study could be considered as low. We further conducted quantitative tests, namely Rosenthal’s Fail-safe N , Begg and Mazumdar’s rank correlation test (Begg and Mazumdar, 1994) and Egger’s test (Egger et al., 1997) in order to test the publication bias more objectively, since the funnel plot can only preliminarily check the publication bias from a subjective point of view (see Table 5).

Based on the value of Rosenthal’s N , the fail-safe number was 45,208, indicating that 45,208 studies contradicting the conclusions would be required to overturn this study. In other words, each observed study would need 426.5 missing studies to invalidate the effect. Since 45,208 was much greater than the criterion number $5m + 10$ (m was the number of original studies), it could be inferred that there was little possibility of publication bias in this study (Rothstein et al., 2006). In the Begg and Mazumdar’s rank correlation test, Kendall’s T was 0.038, $p = 0.283$, $p > 0.05$ (one-tailed), which also showed little possibility of publication bias. However, according to the results of Egger’s test, the Egger regression intercept ($B0$) was 2.408, $t = 3.188$, and was significant [$p = 0.002$, $p < 0.05$ (one-tailed)], indicating that the study yielded publication bias.

The results of the four tests of publication bias were not consistent. Only three of the results (funnel plot, Rosenthal’s N , and Begg’s rank correlation test) suggested that publication bias was not likely to occur. Therefore, we further detected publication bias through Trim and Fill method proposed by Duval and Tweedie (2000). The result indicated that under the random-effects model,

the point estimate for the combined studies was “0.308,” 95% CI [0.275, 0.341]. After using Trim and Fill, the imputed point estimate was “0.225,” 95% CI [0.188, 0.260]. It was calculated that the overall effect size ($r = 0.225$) obtained by the random-effects model was still significant after Trim and Fill method was applied. Besides, only 9.5% of the literature entering the final meta-analysis was unpublished. Although there might be slight publication bias in this study, the main conclusions of this meta-analysis are still valid.

4 Summary and discussion

This study employed a meta-analysis to examine the relationship between field independence and dependence cognitive style and academic achievement of primary and secondary school students. Additionally, it analyzed the influence of various factors, including students’ gender, educational stage, cognitive style measurement instruments, subject area, and type of academic achievement, on this association. The study yielded the following conclusions.

- (1) The field independence-dependence cognitive style had an impact on the academic achievement of primary and secondary school students.

The overall analysis of this study indicated a positive and significant correlation between the field independence-dependence cognitive style and the academic achievement of primary and secondary school students. The effect size of the correlation coefficient was moderately strong and statistically significant ($r = 0.308$, $p < 0.01$), suggesting that students’ cognitive style influences their academic performance. This finding aligns with the conclusions of several scholars (Ates and Cataloglu, 2007; Gennaro et al., 1992; Mousavi et al., 2012; Paramo and Tinajero, 1990). For instance, Mousavi et al. (2012) found that cognitive style was significantly correlated with academic performance in Mathematics, with a predictive effect of $r = 0.580$ ($p < 0.01$). Their study further inferred that cognitive style served as a strong predictor of students’ mathematical performance ($\beta = 0.58$, $p < 0.01$). Moreover, research suggests that students with a field-independent cognitive style generally outperform those with a field-dependent cognitive style (Danili and Reid, 2006; Paramo and Tinajero, 1990; Picciarelli et al., 1995). For example, Paramo and Tinajero (1990) demonstrated a substantial relationship between students’ cognitive style and academic performance, indicating that field-independent students performed better across a broad range of subjects, including Mathematics, Spanish, Natural Sciences, and Social Sciences, compared to their field-dependent peers. This outcome may be attributed to the fact that field-independent students tend to rely on intrinsic motivation and

TABLE 4 Subgroup analysis of the relationship between field independence-dependence cognitive style and academic achievement among students.

Subgroup	Test of heterogeneity			Group noun	<i>k</i>	Effect size and 95% interval			Test of null [2-tail]	
	<i>Q_B</i>	df	<i>P</i>			Point estimation	Lower limit	Upper limit	Z-value	<i>P</i> -value
Sex	1.656	1	0.198	Female	6	0.355	0.309	0.399	14.080	0.000
				Male	3	0.304	0.240	0.366	8.889	0.000
Educational stage	5.952	1	0.015	Primary education	22	0.248	0.221	0.275	17.272	0.000
				Secondary education	81	0.287	0.272	0.301	35.501	0.000
Measurement tool	111.347	5	0.000	CEFT	9	0.386	0.339	0.431	14.753	0.000
				CST	1	0.455	0.335	0.560	6.750	0.000
				DAPT	3	0.088	0.044	0.131	3.898	0.000
				EFT	9	0.350	0.286	0.410	10.143	0.000
				FASP	1	0.334	0.188	0.465	4.338	0.000
				GEFT	83	0.288	0.274	0.303	37.031	0.000
Subject	71.652	5	0.000	Language	15	0.196	0.165	0.227	12.125	0.000
				Mathematics	16	0.310	0.274	0.344	16.142	0.000
				Music	1	0.043	−0.178	0.260	0.378	0.706
				Psychology	13	0.359	0.327	0.390	20.415	0.000
				Science	47	0.300	0.280	0.320	27.403	0.000
				Other	14	0.230	0.195	0.264	12.500	0.000
Academic achievement type	35.083	1	0.000	Academic achievement score	66	0.250	0.233	0.266	28.333	0.000
				Academic achievement skills	40	0.329	0.309	0.349	29.873	0.000

k was the effect size. df, degrees of freedom. Cognitive style measurement instrument: GEFT, Group Embedded Figures Test; CEFT, Children's Embedded Figures Test; EFT, Embedded Figures Test; DAPT, Goodenough Harris Drawing Test: Draw-A-Person test; CST, Cognitive Style Test; FASP, Find-A-Shape Puzzle.

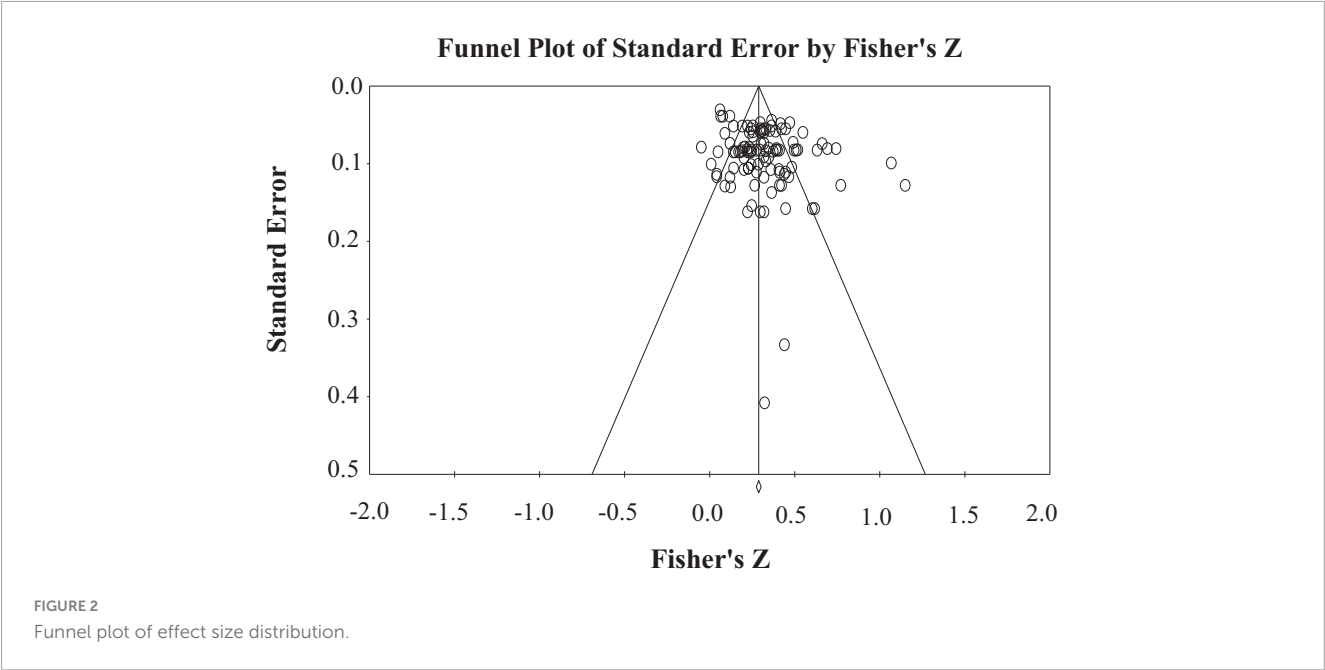


FIGURE 2
Funnel plot of effect size distribution.

TABLE 5 Results of publication bias tests.

Outcome variable	Classic fail-safe <i>N</i>		Begg and Mazumdar rank correlation		Egger's regression intercept				
	Rosenthal's <i>N</i>	<i>Z</i> -value	<i>T</i>	<i>p</i> -value	Intercept	LL	UL	<i>t</i> -value	<i>p</i> -value
Academic achievement	45208	40.524	0.038	0.283	1.895	0.716	3.073	3.188	0.002

T, Kendall's tau; LL, Lower limit; UL, Upper limit.

engage in independent, self-directed learning more frequently than field-dependent students. Additionally, because field-independent students are less influenced by their surrounding environment, they may be better equipped to achieve higher academic success (Paramo and Tinajero, 1990; Witkin et al., 1977).

(2) The cognitive style measurement instrument, subject area, and type of academic achievement significantly moderated the relationship between cognitive style and academic achievement, whereas gender and educational stage did not have a significant impact on the effect size of this relationship.

In the process of evaluating students' cognitive styles, scholars developed a variety of measuring instruments. As for the measuring instruments of cognitive style, inter-group heterogeneity results were significant in the subgroup analysis, which were concordant with Tinajero and Paramo's (1997) findings. Tinajero and Paramo (1997) used two types of cognitive style measuring instruments, namely, Rod and Frame Test (RFT) and Embedded Figures Test (EFT), to study the relationship between academic performance and field independence-field dependence cognitive style among 408 students aged 13–16. The results indicated that for both of the studied genders, the field independence-dependence cognitive style as defined by EFT was a significant source of variance in scores ($p = 0.03$), whereas the cognitive style as defined by RFT was not a significant source of variance.

Although no piece of data has directly confirmed the subject area and type of academic achievement will affect the relationship

between cognitive style and academic achievement among primary and secondary school students, this meta-analysis found that the above-mentioned relationship changed as the subject area and the forms of academic achievement changed. Relevant research evidence have also shown that the score of field independence and dependence cognitive style is related to the subject area as field-independent students are more likely to study Mathematics, Science, Architecture and Engineering, whereas field dependent students tend to select basic education subjects, Social sciences and Psychology (Witkin et al., 1977).

The present study found that gender differences in primary and secondary school students did not affect the relationship between field independence and dependence cognitive style and academic achievement. This was similar to the findings of Mshelua and Lapidus (1990), who studied the relationship between non-western fourth-graders' cognitive style and depth picture perception and found no gender difference between their field independence and dependence cognitive style and depth picture perception through multiple regression analysis. Nevertheless, when Tinajero and Paramo (1997) studied the relationship between middle school students' field independence and dependence cognitive style and academic achievement, they found that gender difference had a very obvious influence on the above-mentioned relationship. They stated that boys who were independent did better in Social Sciences, whereas girls who were independent had a better achievement in Mathematics. Similarly, Paramo and Tinajero (1990) put forth that boys performed better than girls in all disciplines. Those

inconsistent opinions might be due to different contents, samples and areas of the studies.

During the meta-analysis, we categorized students in the basic education phase into primary and secondary schools. The findings indicated that this segmentation of educational stages did not alter the association between students' field-independent and field-dependent cognitive styles and their academic achievements. In other words, the relationship between cognitive style and academic achievement did not differ significantly between primary and secondary school students. This is not fully consistent with the findings of [Paramo and Tinajero \(1990\)](#). [Paramo and Tinajero \(1990\)](#) divided 103 participants into two groups: a group of students aged between 10 and 11 years ($M = 10.6$) and another group of students aged between 12 and 14 years ($M = 12.9$). The results showed that the relationship between the cognitive style and overall score of primary school students was different from that of middle school students ($r = 0.23$).

Finally, we tested the possible publication bias in this study. The results of the publication bias test showed that there was a certain risk of publication bias in this study. We also found that there were few reports on the non-significant effect of the relationship between students' cognitive style and academic achievement. However, this conclusion still needs to be treated with caution and further studies should be conducted to ascertain this area.

To sum up, this meta-analysis conducted an in-depth analysis of the relationship between students' cognitive style (field independence-dependence component) and academic achievement, thus reaching a consistent conclusion that there is a significant positive correlation between students' cognitive style and their academic achievement, and that field independence and dependence cognitive style will affect the of students' academic achievements. This filled the research gap in this research direction to a certain extent. Additionally, the research on the influence of educational stage, cognitive style measurement instrument, subject area and type of academic achievement provides a reference for later research on students' other types of cognitive styles and their relationship with academic achievement or similar meta-analysis research.

5 Limitations and recommendations

This meta-analysis has systematically and scientifically synthesized existing research on the relationship between field independence-dependence cognitive style and academic achievement among primary and secondary school students. By doing so, it contributes to a deeper understanding of students' cognitive differences and their impact on academic performance. However, as with any academic research, certain limitations are unavoidable.

First, meta-analysis as a research method has inherent constraints. One notable limitation is the restricted inclusion of unpublished journal articles, conference papers, and master's theses. The present study included a larger proportion of studies reporting significant effects than those without, which may have introduced publication bias and potentially influenced the findings. To mitigate this issue, future research should aim to incorporate a broader range of unpublished studies, thereby ensuring a more comprehensive and balanced dataset. Moreover, the results

of meta-analyses should always be interpreted with caution, acknowledging the possibility of publication bias.

Second, the selection of moderating variables poses another limitation. When examining factors that may influence the relationship between cognitive style and academic achievement, the choice of moderators plays a crucial role. In this study, five moderating variables were considered: students' gender, educational stage, cognitive style measurement instrument, subject area, and type of academic achievement. While this approach allowed for a more systematic and comprehensive analysis, it also introduced challenges. The limited sample size for certain moderator categories and the uneven distribution of studies across these categories may have affected the reliability of subgroup analyses. Future research should consider refining the selection of moderators and ensuring a more balanced dataset to enhance the robustness of the findings.

Third, among the included studies, some reported multiple effect sizes from the same sample without conducting a multilevel meta-analysis, which may affect the accuracy of effect size estimation. However, our evaluation revealed that although these effect sizes were derived from the same sample, most corresponded to subdivided indicators of different dimensions, and the correlation between effect sizes was relatively low. Based on this assessment, we determined that under the current data structure, the omission of a multilevel meta-analysis had only a minimal impact on the overall pooled estimates. Therefore, we proceeded with the current analytical strategy. Strictly speaking, the failure to apply multilevel meta-analysis for more precise modeling of the nested data structure may, to some extent, compromise the accuracy of effect size estimation. Therefore, it is recommended that future studies, when dealing with similar data structures, further adopt multilevel meta-analysis to enhance the precision and reliability of results, thereby providing more robust statistical support for relevant research conclusions.

This study also provides several recommendations and directions for future research. First, although the term "academic" was not included as a keyword in the document retrieval process, a subsequent inspection confirmed that no relevant literature was omitted. However, future researchers may consider incorporating this term to refine and expand their literature searches.

Second, while this study analyzed multiple variables that may influence the relationship between cognitive style and academic achievement, future research could focus on a smaller set of key variables that demonstrate a significant impact. Additionally, researchers may explore other cognitive style dimensions, such as impulsivity-reflectivity, verbalizer-visualizer, and holist-serialist, to further enrich the understanding of cognitive differences and their academic implications.

Third, the present study focused exclusively on primary and secondary school students. Future research could extend this investigation to other educational levels, including preschool children, college students, and postgraduate students, to determine whether the observed relationships hold across different developmental stages.

Lastly, as this meta-analysis only included studies published in English, future studies could consider incorporating literature published in other languages to capture a more diverse and global perspective on the relationship between cognitive style and academic achievement.

By addressing these limitations and expanding the scope of future research, scholars can further contribute to the understanding of cognitive styles and their influence on academic success, ultimately informing educational practices and interventions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

QX: Writing – original draft, Writing – review & editing, Data curation, Methodology, Conceptualization, Investigation, Supervision, Project administration, Validation. KY: Writing – original draft, Data curation, Conceptualization, Methodology, Investigation, Software. RJ: Data curation, Conceptualization, Methodology, Investigation, Formal analysis, Validation, Writing – review & editing. YQ: Data curation, Conceptualization, Methodology, Investigation, Formal analysis, Software, Writing – review & editing. LT: Data curation, Conceptualization, Methodology, Investigation, Formal analysis, Software, Writing – review & editing. CC: Conceptualization, Methodology, Supervision, Investigation, Project administration, Resources, Writing – review & editing. KS: Conceptualization, Supervision, Project administration, Validation, Funding acquisition, Resources, Writing – review & editing.

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