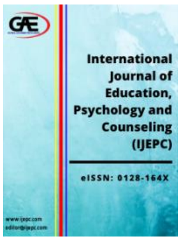
International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071



INTERNATIONAL JOURNAL OF EDUCATION, PSYCHOLOGY AND COUNSELLING (IJEPC)
www.ijepc.com

A COMPARATIVE META-ANALYSIS OF INTEGRATED AND DISCIPLINARY SCIENCE CURRICULA: EFFECTS ON STUDENTS' SCIENTIFIC LITERACY

Zeng Xiangfei[1], Nor Hasnida Che Md Ghazali[2*], Huang Dongyuan[3], Yao Yao[4]

[1] Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia
Email: 2421645693@qq.com
[2] Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia
Email: hasnida@fpm.upsi.edu.my
[3] Junior High School Division, Hainan Micro-city Future School, China
Email: 1016126810@qq.com
[4] Senior High School Division, Hainan Micro-city Future School, China
Email: 2199162749@qq.com
[*] Corresponding Author

Article Info:

Article history:
Received date: 05.05.2025
Revised date: 27.05.2025
Accepted date: 16.06.2025
Published date: 30.06.2025

To cite this document:

Xeng, X., Ghazali, N. H. C. M., Huang, D., & Yao, Y. (2025). A Comparative Meta-Analysis Of Integrated And Disciplinary Science Curricula: Effects On Students' Scientific Literacy. *International Journal of Education, Psychology and Counseling, 10* (58), 1109-1125.

DOI: 10.35631/IJEPC.1058071.

Abstract:

Amid rapid scientific and technological progress and growing interdisciplinarity, scientific literacy has become critically important. This meta-analysis investigated the comparative effects of integrated and disciplinary science curricula on students' scientific literacy, synthesizing findings from nine studies published between 2007 and 2022, encompassing a total of 14 datasets. The results revealed a higher overall standardized mean difference (*SMD* = 0.497) for the integrated science curriculum, surpassing that of the disciplinary curriculum. The most substantial improvements were observed in scientific understanding (*SMD* = 0.637) and scientific attitude and responsibility (*SMD* = 0.620). Across educational stages, the strongest effect was found at the primary level (*SMD* = 1.528), followed by a medium but significant effect at the lower secondary level (*SMD* = 0.255), while the effect at the upper secondary level was medium (*SMD* = 0.372) and statistically non-significant. Meta-regression analysis showed that sample size had no significant impact, whereas implementation duration was a significant negative predictor of student outcomes (p = .001). These findings underscore the effectiveness of integrated science curricula in enhancing scientific literacy and provide valuable insights for future curriculum development.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Keywords:

Integrated Science Curriculum, Disciplinary Science Curriculum, Scientific Literacy, Educational Stages, Meta-Analysis

Introduction

The Fourth Industrial Revolution, characterized by the interconnection of systems and the dissolution of physical boundaries, has fundamentally changed society (Schwab, 2017). These changes, such as artificial intelligence, the Internet of Things, and biotechnology, require multidisciplinary collaboration to meet opportunities and challenges (OECD, 2018). From this perspective, cultivating scientific literacy is undoubtedly one of the primary goals of education. It entails the comprehension of scientific concepts, the application of critical analysis, the resolution of issues, and the formulation of well-informed decisions in a variety of real-world scenarios (Drake, 2004; Laugksch, 2000).

Curriculum design is a critical component of science education that significantly contributes to the development of students' scientific literacy. Two models are commonly adopted to implement this goal: the integrated science curriculum and the disciplinary science curriculum. Integrated science curricula encourage higher-order thinking (Richardson & Showalter, 1967; Winarno et al., 2020). They achieve this by facilitating students' integration of scientific knowledge into practical contexts and by emphasizing interdisciplinary connections. By contrast, disciplinary science curricula emphasize in-depth exploration of specific disciplines, laying a robust foundation for advanced study and specialization (Åström, 2008; Pan, 2004).

Although both models offer theoretical advantages, their practical effectiveness in promoting scientific literacy remains uncertain. Research indicates that integrated science curricula are frequently implemented; however, there is inadequate quantitative evidence to verify their effects on educational outcomes (Faulkner, 2012). Additionally, there is a dearth of research conducted on interdisciplinary competencies, which, as a vital aspect of scientific literacy, remain underexplored in current literature (Wang & Song, 2021). In international assessments such as TIMSS and PISA, the focus on disciplinary knowledge takes precedence over interdisciplinary competencies (Mullis & Martin, 2017; OECD, 2017), further marginalizing the evaluation of both curriculum models. The generalizability of the few existing studies on the effects of the two curriculum models on the development of students' scientific literacy is also limited by the reliance on small samples (Zhu, 2017).

Therefore, this study conducts a systematic meta-analysis to synthesize current empirical evidence and rigorously assess the comparative effects of integrated and disciplinary science curricula on students' scientific literacy, including its multiple dimensions and across various educational contexts. Specifically, this study aims to:

1. Determine the overall effect of curriculum model on students' scientific literacy;
2. Examine differences in effect sizes across categorical variables, including dimensions of scientific literacy and educational stages;
3. Investigate whether two continuous variables—sample size and duration of implementation—significantly moderate the observed effects.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071
By addressing these objectives, the study seeks to generate data-driven insights that can inform future curriculum development and instructional practice.

Literature Review

The core goal of science education is to develop students' scientific literacy, which involves not only understanding scientific concepts but also applying them in real-world situations. Science itself is both a body of knowledge and a process of inquiry (Lederman, 2019). It evolves continuously, shaped by social, cultural, and historical contexts (Ziman, 2000). These dynamic characteristics provide a solid foundation for science education, emphasizing scientific inquiry, method, and the spirit of discovery as important components of scientific literacy (Allchin, 2011). Scientific literacy has expanded over time from a narrow focus on knowledge to a multidimensional framework. Early definitions, such as Miller's (1983), highlighted the importance of understanding scientific terms, mastering inquiry processes, and recognizing the role of science in society. Later, Bybee (1997) and Holbrook and Rannikmae (2009) emphasized evidence-based decision-making and ethical reasoning. In China, the Compulsory Education Science Curriculum Standards (2022 edition) (Ministry of Education [MOE], 2022) defines four dimensions of scientific literacy: scientific understanding, scientific thinking, scientific inquiry and practice, and scientific attitude and responsibility.

Each of the two curriculum models has its own characteristics in terms of theoretical. Integrated science curricula promote creativity and problem-solving but often face challenges in implementation, such as difficulty in integrating curriculum content and learning transfer (Mason, 1996). Disciplinary science curricula provide logical structures for in-depth learning but may compartmentalize knowledge (Schmidt et al., 2005). The choice between these models varies by country and educational level. For instance, the U.S. often uses integrated science curricula in lower secondary schools but shifts to disciplinary models in upper secondary schools, while not all states are set up this way (National Research Council, 2013). Finland employs integrated approaches in basic education but offers more specialized options at higher levels (Halinen, 2018). In China, integrated science curricula are implemented at the elementary school level; disciplinary science curricula parallel the integrated science curriculum model at the lower secondary school level but are dominated by subdisciplines; and disciplinary science curricula are adopted at the upper secondary school level (MOE, 2022). Although both curriculum models are theoretically well-founded and differ across national contexts, empirical findings remain inconclusive regarding their relative effectiveness in fostering students' scientific literacy.

Integrated science curricula have been shown to enhance students' interdisciplinary thinking and engagement (Anwar et al., 2022; Czerniak & Johnson, 2014; Khan, 2024). Disciplinary approaches are often more effective in promoting conceptual understanding and inquiry skills (Schweingruber et al., 2012). However, Familari et al. (2013) observed that disciplinary biology curricula benchmarks enhanced university learning, while a focus on open inquiry in secondary education risked misalignment with tertiary expectations. Context plays a crucial role in curriculum effectiveness, as Ogunkola and Fayombo (2009) found that integrated science curricula worked well in urban schools but had limited success in rural areas due to a shortage of teaching resources and low student interest in learning.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Meta-analysis offers a way to synthesize these findings and address gaps in individual studies. Recent years have witnessed a proliferation of meta-analytical studies focusing on science education, particularly examining the effectiveness of diverse instructional strategies and curricular designs. These studies have explored a variety of themes, including inquiry-based learning (Furtak et al., 2012), student-centered teaching (Baysal et al., 2023), problem-based and project-based learning (Funa & Prudente, 2021; Hukom et al., 2023), the use of immersive and augmented reality (Akbay & Çeliker, 2023; Yilmaz & Batdi, 2021), science-technology-society (STS) approaches (Acut & Antonio, 2023a), and contextualized curriculum frameworks (Morgado et al., 2022). Each of these topics reflects growing efforts to enhance students' scientific engagement, process skills, conceptual understanding, and broader scientific literacy across educational contexts.

In addressing the efficacy of these interventions, many meta-analyses have applied moderator analyses to investigate the influence of both categorical and continuous variables on learning outcomes. Categorical moderators such as educational stages (e.g., primary, lower secondary, upper secondary) and disciplinary domains (e.g., physics, chemistry, biology) were commonly examined to determine the differential effectiveness of interventions (Akbay & Çeliker, 2023; Winarno et al., 2020; Yildirim, 2022). Similarly, scientific literacy has been dissected into multiple dimensions—such as scientific understanding, inquiry skills, attitudes, and interdisciplinary competence—providing further granularity in the analysis of science education outcomes (Faulkner, 2012; Wang & Song, 2021).

Continuous variables such as sample size and implementation duration have also been examined as moderators of effect size. A negative correlation between sample size and effect size was observed in several studies, with smaller samples tending to report larger effects, and larger samples producing more conservative but stable results (Akbay & Çeliker, 2023; Yıldırım, 2022; Yıldırım & Şahin, 2023). However, some findings indicated that effect sizes remained significant across sample size groups, suggesting it may not always function as a primary moderator (Antonio & Prudente, 2023). The role of implementation duration also showed mixed results. While longer interventions were sometimes associated with stronger effects (Akay & Kanadli, 2021; Hukom et al., 2023), other studies found no clear relationship between duration and learning outcomes (Acut & Antonio, 2023b; Antonio & Prudente, 2023).

Despite these advances, a notable research gap persists regarding the comparative effects of integrated versus disciplinary science curricula on students' scientific literacy. This lacuna underscores the need for rigorous, data-driven investigations that clarify the relative contributions of different curricular approaches to fostering scientific literacy in varied educational contexts.

Methodology

This study used a meta-analytic research method to compare the effects of integrated and disciplinary science curricula in enhancing students' scientific literacy. Meta-analysis is a quantitative method that synthesizes the results of multiple independent studies to reveal overall patterns and trends (Schroeder et al., 2007; Shorten et al., 2025). It helps provide evidence-based support for curriculum design and educational policy by consolidating diverse research findings (Ouyang & Xu, 2024).

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Data Sources and Search Strategies

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) to ensure transparency and reproducibility. Searches were conducted using several academic databases, including Google Scholar, Web of Science, SpringerLink, ScienceDirect, ProQuest, Wiley, SAGE, JSTOR, Taylor & Francis Online, ERIC, CNKI, and Wanfang.

Keywords were selected to capture relevant studies and combined with Boolean operators. The main search terms included 'integrated science curriculum,' 'disciplinary science curriculum,' 'science curriculum effects,' 'scientific literacy,' and 'experimental research.' Boolean operators such as AND, OR, and NOT helped refine the search results.

To ensure the selected studies aligned with the research objectives, inclusion criteria were defined as follows:

1. Empirical studies comparing integrated and disciplinary science curricula in terms of their impact on scientific literacy;
2. Use of experimental or quasi-experimental designs;
3. Participants were primary, lower secondary, or upper secondary school students;
4. Assessment tools demonstrate validity and reliability;
5. Quantitative data were provided for both experimental and control groups, including implementation durations, sample sizes, post-test means and standard deviations;
6. Publications were in English or Chinese.

The search was conducted in January 2025, and studies that did not meet these criteria were excluded. Initially, 319 studies were identified. After removing duplicates and screening titles, abstracts, and full texts, nine papers (Alghamdi, 2017; Chen, 2011; Liu, 2007, 2008; Putica & Trivic, 2017; Shao, 2022; Weng, 2022; Xie et al., 2013; Zhu, 2017) comprising 14 sub-studies were included in the final analysis. For studies with multiple results, each result was analyzed separately to ensure data accuracy.

Data Analysis

The meta-analysis was conducted using Stata 16 software to evaluate the effects. Data extraction focused on quantitative data and study characteristics, including authors, publication year, and scientific literacy dimensions.

To analyze the effects across different scientific literacy dimensions and educational stages, this study adopted the classification framework outlined in China's Compulsory Education Science Curriculum Standards (2022 edition) (MOE, 2022). The framework defines scientific literacy as comprising four core dimensions: Scientific Understanding, which refers to the comprehensive cognition of objective phenomena developed through the understanding of scientific concepts, laws, and principles; Scientific Thinking, which denotes a scientific mode of reasoning that explores the essence, internal patterns, and interrelationships of objective phenomena, including the construction of models, inferential reasoning, and innovative thinking; Scientific Inquiry and Practice, which involves the development of competencies in scientific exploration, technological and engineering practices, and autonomous learning, achieved through engaging in investigations and solving real-world problems; and Scientific Attitude and Responsibility, which refers to the gradual development of a positive attitude toward science and a sense of social responsibility, grounded in an understanding of the nature

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

of science and the interconnections among science, technology, society, and the environment. Educational stages were categorized into primary, lower secondary, and upper secondary school levels, allowing for a comparative analysis of curriculum effectiveness.

Effect sizes were calculated separately for each dimension and educational stage to identify patterns and variations, using the standardized mean difference (*SMD*) computed via Hedges' *g*, which adjusts for small sample bias and quantifies the impact of interventions on student outcomes. Following Hedge and Olkin's (2014) criteria, effect sizes were categorized as small (0.2), medium (0.5), and large (0.8). Due to substantial heterogeneity among studies, a random-effects model was employed. A significant result from Cochran's *Q*-test ($p < .05$) confirmed this heterogeneity, supporting the use of this model (DerSimonian & Laird, 1986).

Additionally, regression analyses were conducted to examine the effects of sample size and implementation duration on effect sizes, providing insights into how these factors affect the overall outcomes (Pigott & Polanin, 2020). Finally, publication bias was assessed using a funnel plot, and Egger's test was applied to detect small-study effects (Egger et al., 1997).

Results

Characteristics of Included Studies

This meta-analysis included nine papers published between 2007 and 2022 with 14 available datasets. Table 1 summarizes the core characteristics of these studies, including authorship, publication year, and the dimensions of scientific literacy assessed.

Table 1: Source Characteristics

Article No.	Author/s	Year of Publication	Dimension of Scientific Literacy
1	Xie Lixuan et al.	2013	Overall Scientific Literacy
2	Liu Jianzhi	2008	Overall Scientific Literacy
3	Liu Jiang	2007	Overall Scientific Literacy
4	Weng Aiping	2022	Scientific Inquiry and Practice
5.1	Zhu Chenpeng	2017	Scientific Understanding
5.2			Scientific Understanding
5.3			Scientific Understanding
5.4			Scientific Attitude and Responsibility
5.5			Scientific Thinking
6	Shao Chuanhua	2022	Overall Scientific Literacy
7.1	Lin Chingchen	2011	Scientific Understanding
7.2			Scientific Understanding
8	Amani K. H. Alghamdi	2017	Overall Scientific Literacy
9	Katarina B. Putica	2017	Scientific Understanding

As shown in Table 2, the majority of studies focused on overall scientific literacy (36%) and scientific understanding (43%), while fewer studies addressed scientific thinking (7%), scientific inquiry and practice (7%), and scientific attitude and responsibility (7%). This imbalance suggests that most research prioritizes knowledge acquisition over other dimensions

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

of scientific literacy. Regarding educational stages, lower secondary school studies dominated (65%), with fewer studies on primary (21%) and upper secondary school levels (14%).

Table 2: Number of Articles according to Scientific Literacy Dimension and Educational Stage

Category		Frequency (n=14)	Percentage (%)
Scientific Literacy Dimension	Overall Scientific Literacy	5	36
	Scientific Understanding	6	43
	Scientific Thinking	1	7
	Scientific Inquiry and Practice	1	7
	Scientific Attitude and Responsibility	1	7
Educational Stage	Lower Secondary Education	9	65
	Upper Secondary Education	2	14
	Primary Education	3	21

The quantitative data shown in Table 3 include implementation durations (ID), sample sizes (N), means (M), and standard deviations (SD). The results indicate that in most studies, the mean scores of the integrated science curriculum were typically higher than those of the disciplinary curriculum. However, some studies reported small or even insignificant differences between the two types.

Table 3: Quantitative Data

Article No.	ID	Integrated Science Curriculum			Disciplinary Science Curriculum		
		N1	M1	SD1	N2	M2	SD2
1	Three years	47	45.57	15.85	49	39.49	12.56
2	Three years	321	55.55	15.46	362	53.46	15.06
3	Three years	20	68.33	6.66	20	68.90	6.36
4	Three years	85	9.45	0.74	83	9.41	0.68
5.1	Three years	34	7.53	1.91	34	6.65	2.07
5.2		31	3.85	0.54	27	3.92	0.84
5.3		32	3.64	0.80	26	3.44	0.97
5.4		33	4.26	0.70	28	3.81	0.72
5.5		34	3.47	0.90	33	3.27	1.10
6	Three years	572	29.64	7.31	808	27.36	7.02
7.1	Three weeks	32	18.37	1.48	32	15.06	2.28
7.2		32	15.38	2.70	32	13.19	2.25
8	Two semesters	36	14.08	1.42	41	11.39	1.20
9	One semester	125	10.35	2.20	133	8.12	3.69

Overall Effect Size from Forest Plot

The meta-analysis revealed that integrated science curricula had a moderate overall effect size (*SMD* = 0.497, 95% *CI*: [0.277, 0.718], $p < .001$), as shown in Table 4. According to Cohen's classification (Cohen, 2013), this indicates a medium effect, suggesting that integrated science curricula are generally more effective than disciplinary science curricula in fostering scientific literacy.

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Table 4: Overall Effect Size

Study Count	*Z*-value	*p*-value	Effect Size	95% *CI* (Lower–Upper)	*Standard Error*
14	4.42	0.000	0.497	0.277 - 0.718	0.10

The forest plot in Figure 1 further illustrates variations in the results of different studies across specific dimensions of scientific literacy. For instance, in Article No. 3 (overall scientific literacy) and Article No. 5.2 (scientific understanding), disciplinary science curricula showed a slight advantage over integrated science curricula (see Table 5), though the differences did not reach statistical significance. This suggests that disciplinary science curricula may have certain advantages in the transmission of knowledge within specific domains.

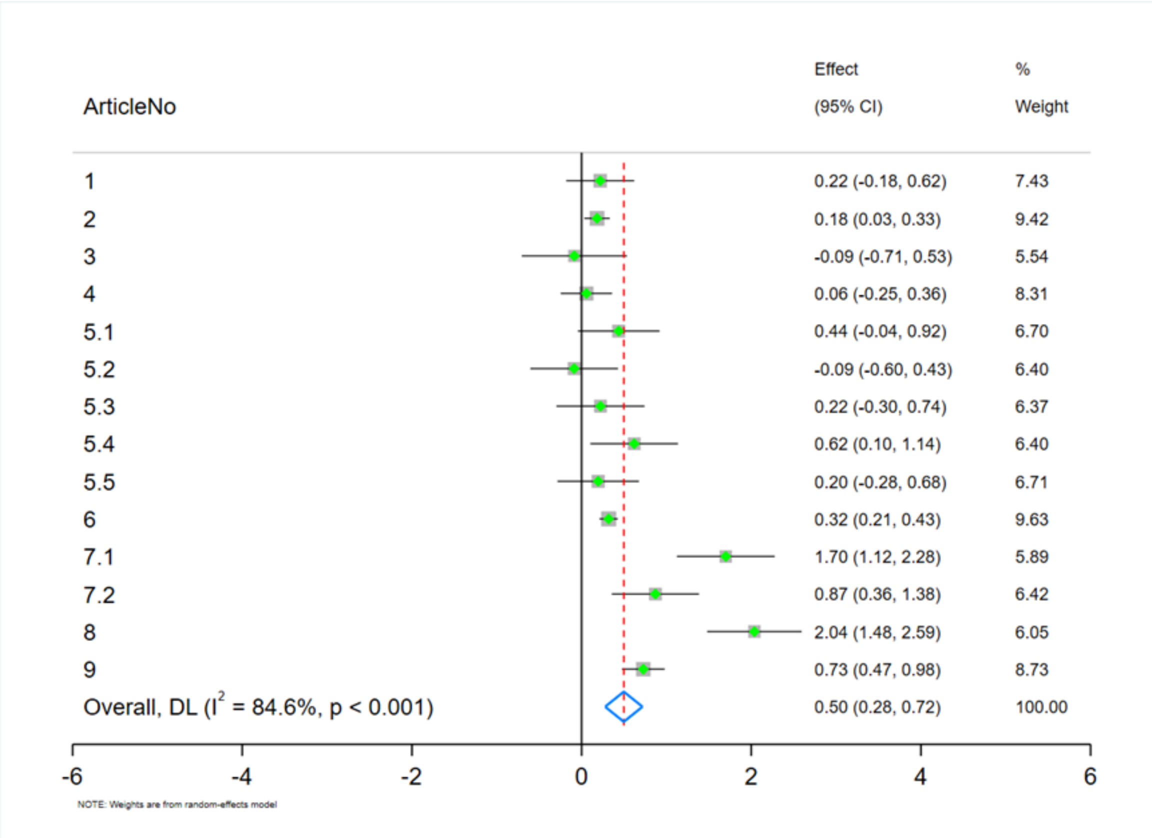


Figure 1: Forest Plot

Table 5: Effect Sizes of 14 Research Studies

Article No.	Hedges' *g*	*CI* Lower Limit	*CI* Upper Limit	Weight
1	0.220	-0.182	0.621	7.43
2	0.182	0.031	0.332	9.42
3	-0.086	-0.706	0.534	5.54
4	0.056	-0.246	0.359	8.31
5.1	0.438	-0.044	0.919	6.70
5.2	-0.087	-0.604	0.429	6.40
5.3	0.223	-0.296	0.742	6.37
5.4	0.620	0.104	1.136	6.40

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Article No.	Hedges' *g*	*CI* Lower Limit	*CI* Upper Limit	Weight
5.5	0.196	-0.285	0.676	6.71
6	0.319	0.211	0.427	9.63
7.1	1.700	1.123	2.277	5.89
7.2	0.869	0.355	1.383	6.42
8	2.037	1.480	2.593	6.05
9	0.727	0.475	0.979	8.73

Test of Heterogeneity

Cochran's *Q* statistic and related metrics were used to evaluate the heterogeneity among the 14 studies and to test the consistency of the extracted data. The results of the heterogeneity test (see Table 6) indicate that the Cochran's *Q* statistic was 84.46, with a significant *p*-value ($p < .001$), demonstrating substantial heterogeneity among the studies and justifying the use of a random effects model. Additionally, the I^2 value of 84.6% suggests that the variance in effect sizes primarily arises from genuine differences between studies rather than random errors.

Table 6: Heterogeneity Test

Q-value	*p*-value	I^2	*H*-Statistic
84.46	0.000	84.6%	2.549

Subgroup Analysis

Subgroup analysis reveals variations in effect sizes across scientific literacy dimensions and educational stages (Tables 7 and 8). Overall science literacy (*SMD* = 0.480) had a moderate effect. The largest effect size was observed in the scientific understanding dimension (*SMD* = 0.637, 95% *CI*: [0.223, 1.051]). The effects of scientific thinking (*SMD* = 0.196) and scientific inquiry and practice (*SMD* = 0.056) were small and not statistically significant, as their 95% confidence intervals ([-0.285, 0.676] and [-0.246, 0.359], respectively) included zero. Scientific attitude and responsibility showed a medium-to-high effect size (*SMD* = 0.620).

Across educational stages, integrated science curricula showed the highest impact at the primary level (*SMD* = 1.528, 95% *CI*: [0.826, 2.229]), followed by lower secondary education (*SMD* = 0.255, 95% *CI*: [0.174, 0.336]), and upper secondary education (*SMD* = 0.372, not statistically significant).

Table 7: Effect Size by Scientific Literacy

Subgroup	Hedges' *g*	95% *CI* (Lower–Upper)	*Q*	*p*-value	I^2
Overall Scientific Literacy	0.480	0.123-0.838	41.56	0.000	90.4%
Scientific Understanding	0.637	0.223-1.051	24.98	0.000	80.0%
Scientific Thinking	0.196	-0.285-0.676	0.00	0.000	-
Scientific Inquiry and Practice	0.056	-0.246-0.359	0.00	0.000	-
Scientific Attitude and Responsibility	0.620	0.104-1.136	0.00	0.000	-
Combined Effect Size	0.497	0.277-0.718	84.46	0.000	84.6%

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Table 8: Effect Size by Educational Stage

Subgroup	Hedges' *g*	95% *CI* (Lower–Upper)	*Q*	*p*-value	I^2
Primary Education	1.528	0.826-2.229	9.82	0.007	79.6%
Lower Secondary Education	0.255	0.174-0.336	8.19	0.415	2.3%
Upper Secondary Education	0.372	-0.418-1.162	5.66	0.017	82.3%
Combined Effect Size	0.497	0.277-0.718	84.46	0.000	84.60%

Meta-Regression Analysis

Meta-regression analysis examined the influence of sample size and implementation duration on effect size. Results indicated that sample size had no significant effect (p = .580), while implementation duration showed a significant negative correlation with effect size (p = .001), as shown in Table 9.

Table 9: Results of Meta-Regression Analysis by Sample Size and Duration of Implementation

Category	Parameter	*B* (*Unstd. Coeff.*)	*SE*	*B* (*Std. Coeff.*)	*t*-value	*p*-value
Total Sample Size	Intercept	0.57824	0.20248		2.86	0.014
	Predictor	-0.00025	0.00045	0.00637	-0.57	0.580
Duration of Implementation	Intercept	1.34415	0.21210		6.34	0.000
	Predictor	-0.00197	0.00043	-0.79160	-4.56	0.001

Publication Bias

A funnel plot (see Figure 2) and Egger's test were used to assess publication bias. The funnel plot showed slight asymmetry, but Egger's test results (p = .263) confirmed that bias was not significant. These findings validate the reliability of the study's conclusions.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

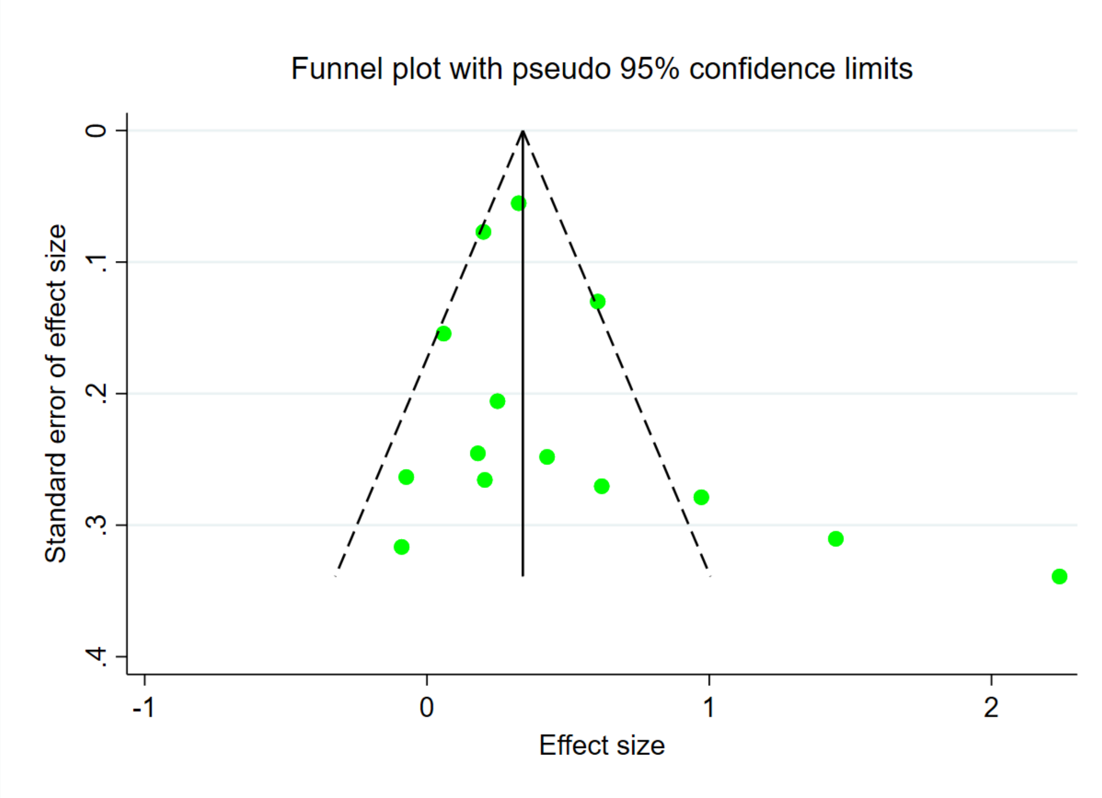


Figure 2: Funnel Plot

Discussion

This study demonstrates that integrated science curricula are generally more effective than disciplinary science curricula, particularly in enhancing students' scientific literacy, although disciplinary curricula still show certain advantages in specific knowledge domains. Osborne (2010) emphasized that disciplinary science curricula help cultivate students' structured argumentation, critical thinking, and logical reasoning. Zhang and Shen (2015) further pointed out that disciplinary science curricula facilitate the construction of clear conceptual frameworks, enhance problem-solving strategies, reinforce disciplinary boundaries, and reduce cognitive overload. Additionally, a study by You et al. (2018) on the topic of carbon cycling found that interdisciplinary understanding poses greater challenges than single-disciplinary knowledge acquisition, indicating that current integrated science curricula still require improvement in terms of content coherence and instructional design.

The heterogeneity test results in this study revealed significant variation among the included studies ($I^2 = 84.6\%$, $Q = 84.46$, $p < .001$), consistent with the view of Pigott and Polanin (2020), who noted that high heterogeneity is common in meta-analyses of educational interventions due to differences in sample characteristics, curricular content, and pedagogical strategies. Therefore, conducting subgroup analyses is particularly meaningful in this context.

Among the various dimensions of scientific literacy, scientific understanding yielded the highest effect size (*SMD* = 0.637), suggesting that integrated science curricula effectively enhance students' mastery of core scientific concepts. This finding aligns with Osborne's (2010) view that multidisciplinary integration enhances the comprehension of essential scientific ideas. The dimension of scientific attitude and responsibility also showed a relatively strong effect

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071
(*SMD* = 0.620), suggesting that integrated science curricula can promote students' sense of responsibility and engagement in science (Jho et al., 2014). However, the effect sizes for scientific thinking (*SMD* = 0.196) and scientific inquiry and practice (*SMD* = 0.056) were small and not statistically significant. This may be due to the fact that current integrated curricula have not fully supported the development of higher-order thinking and inquiry skills in practice. Anderson (2013) and Linn et al. (2013) argued that the development of scientific thinking requires integration into authentic real-world contexts that involve reflective and inferential processes, while scientific inquiry relies heavily on hands-on experimental learning. Slavin et al. (2014) also suggested that although cooperative and inquiry-based teaching approaches show promise, their effectiveness depends heavily on high-quality implementation.

A valuable explanation for the observed differences across scientific literacy dimensions can be found in the theoretical framework of Pan (2004), who suggested that integrated science curricula are more suitable for teaching active knowledge, which is closely tied to real-life contexts and easily transferable and applicable. In contrast, disciplinary science curricula are more effective in delivering inert knowledge, which is often factual and less readily transferable. This conceptual distinction helps explain why integrated science curricula produced stronger outcomes in scientific understanding, but were less effective in dimensions that require abstract reasoning or structured scientific inquiry.

In the analysis by educational stage, the effect size was highest at the primary level (*SMD* = 1.528), consistent with the recommendation of the National Research Council (2012) that younger students benefit from broad, context-based, and integrative approaches to science education. The significant effect observed at the lower secondary level (*SMD* = 0.255) suggests that students at this developmental stage, transitioning toward abstract thinking, can still benefit from integrated science curricula (Froyd & Ohland, 2005). The upper secondary level showed a moderate effect size (*SMD* = 0.372), although it was not statistically significant—likely due to the increasing cognitive demands and content specialization required at this stage, where disciplinary science curricula may hold comparative advantages (Bybee, 1997).

These stage-based differences are also consistent with Piaget's theory of cognitive development. Huitt and Hummel (2003) noted that students in the concrete operational stage (ages 7–12) are more suited to experiential and context-rich learning activities, whereas those in the formal operational stage (ages 12 and above) are more capable of engaging with abstract scientific concepts and theoretical reasoning. Accordingly, science curricula should be developmentally appropriate and aligned with students' cognitive levels in order to optimize learning outcomes.

The meta-regression analysis revealed that sample size had no statistically significant predictive effect on effect size (p = .580), which contrasts with the findings of Slavin and Smith (2009), who reported that smaller-sample studies tend to yield larger effect sizes. This discrepancy in the present study may be attributable to the limited number of studies included in the analysis, highlighting the need for future research based on larger samples.

In contrast, implementation duration showed a significant negative correlation with effect size (p = .001), suggesting that longer interventions do not necessarily yield better results. This may be due to reduced instructional consistency, loss of curricular coherence, or declining student motivation over time. Shimwell et al. (2023) found that short-term interventions were effective

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

in improving students' perceptions of scientists, but such effects diminished over the course of a year. Similarly, Eilam and Reiter (2014) found that in long-term implementations (more than one year), students in self-regulated learning (SRL) environments outperformed those in traditional teacher-controlled (CT) settings, indicating that long-term effectiveness may depend on the extent to which curriculum structures align with learner autonomy and motivation.

Conclusion

This meta-analysis confirms that integrated science curricula are moderately more effective than disciplinary science curricula in enhancing students' scientific literacy, particularly in scientific understanding and scientific attitude and responsibility. Despite their strengths, integrated science curricula show limited impact on scientific thinking and scientific inquiry and practice, highlighting areas for improvement. These findings offer practical implications for curriculum designers and educators, especially in primary and lower secondary education. Future research should explore long-term implementation effects, curriculum fidelity, and the balance between integration and disciplinary depth to optimize science learning outcomes.

Acknowledgements

This research was not funded by any grant.

References

Acut, D., & Antonio, R. (2023). Effectiveness of science-technology-society (STS) approach on students' learning outcomes in science education: Evidence from a meta-analysis. *Journal of Technology and Science Education*, *13*(3), 718–739.

Akay, C., & Kanadli, S. (2021). The effect of REACT strategy on achievement in science education: A mixed research synthesis. *Journal of Baltic Science Education*, *20*(6), 868–880.

Akbay, E., & Çeliker, H. D. (2023). The effect of immersive reality on science learning: A meta-analysis. *Malaysian Online Journal of Educational Technology*, *11*(3), 158–172.

Alghamdi, A. K. (2017). The effects of an integrated curriculum on student achievement in Saudi Arabia. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(9), 6079–6100.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education*, *95*(3), 518–542.

Anderson, C. W. (2013). Perspectives on science learning. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Handbook of research on science education* (pp. 3–30). Routledge.

Antonio, R., & Prudente, M. (2023). Effects of inquiry-based approaches on students' higher-order thinking skills in science: A meta-analysis. *International Journal of Education in Mathematics, Science and Technology*, *12*, 251–281. https://doi.org/10.46328/ijemst.3216

Anwar, S., Menekse, M., Guzey, S., & Bryan, L. A. (2022). The effectiveness of an integrated STEM curriculum unit on middle school students' life science learning. *Journal of Research in Science Teaching*, *59*(7), 1204–1234.

Åström, M. (2008). *Defining integrated science education and putting it to test* (Doctoral dissertation, Linköping University, Linköping, Sweden). *ProQuest Dissertations & Theses*. (UMI No. 31250834)

Baysal, Y. E., Mutlu, F., & Nacaroglu, O. (2023). The effectiveness of student-centered teaching applications used in determining motivation toward science learning: A meta-

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071
analysis study. *International Journal of Psychology and Educational Studies*, *10*(1), 1–21.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices* (ERIC Reproduction Service No. ED461491). ERIC.

Chen, L. C. (2011). The effects of integrated information literacy in science curriculum on first-grade students' memory and comprehension using the Super3 model. *Knowledge Management & E-Learning*, *3*(3), 399.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Czerniak, C. M., & Johnson, C. C. (2014). Interdisciplinary science teaching. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. 2, pp. 395–411). Routledge.

DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, *7*(3), 177–188.

Drake, S. M. (2004). *Meeting standards through integrated curriculum*. Association for Supervision and Curriculum Development.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ*, *315*(7109), 629–634.

Eilam, B., & Reiter, S. (2014). Long-term self-regulation of biology learning using standard junior high school science curriculum. *Science Education*, *98*(4), 705–737.

Familari, M., Da Silva, K. B., Rayner, G., Young, J., Cross, A., & Blanksby, T. (2013). Scientific inquiry skills in first year biology: Building on pre-tertiary skills or back to basics? *International Journal of Innovation in Science and Mathematics Education*, *21*(1), 1–17.

Faulkner, S. F. (2012). *Science literacy: Exploring middle-level science curriculum structure and student achievement* (Doctoral dissertation, University of Hartford). *ProQuest Dissertations and Theses Global*. (UMI No. 3518573)

Froyd, J. E., & Ohland, M. W. (2005). Integrated engineering curricula. *Journal of Engineering Education*, *94*(1), 147–164.

Funa, A. A., & Prudente, M. S. (2021). Effectiveness of problem-based learning on secondary students' achievement in science: A meta-analysis. *International Journal of Instruction*, *14*(4), 69–84.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research*, *82*(3), 300–329.

Halinen, I. (2018). The new educational curriculum in Finland. *Improving the Quality of Childhood in Europe*, *7*, 75–89.

Hedges, L. V., & Olkin, I. (2014). *Statistical methods for meta-analysis*. Academic Press.

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education*, *4*(3), 275–288.

Huitt, W., & Hummel, J. (2003). Piaget's theory of cognitive development. *Educational Psychology Interactive*, *3*(2), 1–5. Retrieved from http://chiron.valdosta.edu/whuitt/col/cogsys/piaget.html

Hukom, J., Prihatmojo, A., Manaf, A., Suciati, I., & Ratau, A. (2023). Integration of blended learning and project-based learning (BPjBL) on achievement of students' learning goals: A meta-analysis study. *Pegem Journal of Education and Instruction*, *13*(4), 274–281.

EISSN : 0128-164X
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Jho, H., Yoon, H.-G., & Kim, M. (2014). The relationship of science knowledge, attitude and decision making on socio-scientific issues: The case study of students' debates on a nuclear power plant in Korea. *Science & Education*, *23*, 1131–1151.

Khan, A. (2024). Assessing the impact of interdisciplinary education on student engagement and achievement. *Frontiers in Interdisciplinary Educational Methodology*, *1*(2), 44–50.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education*, *84*(1), 71–94. https://doi.org/10.1002/(SICI)1098-237X(200001)84:1<71::AID-SCE6>3.0.CO;2-C

Lederman, N. G. (2019). Contextualizing the relationship between nature of scientific knowledge and scientific inquiry: Implications for curriculum and classroom practice. *Science & Education*, *28*, 249–267.

Linn, M. C., Davis, E. A., & Bell, P. (2013). *Internet environments for science education*. Routledge.

Liu, J. (2007). *Analysis of differences between students in integrated science curriculum systems and traditional disciplinary curriculum systems* (Master's thesis, Hunan Normal University).

Liu, J. (2008). Analyzing students' mastery of scientific knowledge in integrated and disciplinary science curricula. *Educational Measurement and Evaluation: Theoretical Edition*, *11*, 4.

Mason, T. C. (1996). Integrated curricula: Potential and problems. *Journal of Teacher Education*, *47*(4), 263–270.

Miller, J. D. (1983). Scientific literacy: A conceptual and empirical review. *Daedalus*, *112*(2), 29–48. JSTOR.

Ministry of Education of the People's Republic of China. (2022). *Compulsory education science curriculum standards (2022 edition)*. Retrieved from http://www.moe.gov.cn

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & the PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264–269. https://doi.org/10.1136/bmj.b2535

Morgado, S., Leite, L., & Dourado, L. (2022). Teaching for the contextualised learning of science: A checklist-based science curriculum analysis. *Journal of Turkish Science Education*, *19*(4), 1072–1095.

Mullis, I. V., & Martin, M. O. (2017). *TIMSS 2019 assessment frameworks*. ERIC.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academy of Sciences.

National Research Council. (2013). *Next generation science standards: For states, by states*. The National Academies Press. https://doi.org/10.17226/18290

OECD. (2017). *PISA 2015 assessment and analytical framework: Science, reading, mathematics, financial literacy, and collaborative problem solving*. OECD Publishing. https://doi.org/10.1787/9789264281820-en

OECD. (2018). *The future of education and skills: Education 2030 – The future we want (E2030 position paper)*. OECD Publishing. https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

Ogunkola, B. J., & Fayombo, G. A. (2009). Investigating the combined and relative effects of some student-related variables on science achievement among secondary school students in Barbados. *European Journal of Scientific Research*, *37*(3), 481–489.

International Journal of Education, Psychology and Counseling
EISSN : 0128-164X
IJEPC
Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071
Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science*, *328*(5977), 463–466.
Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: A multilevel meta-analysis. *International Journal of STEM Education, 11*(1), 7.
Pan, S. D. (2004). *From disciplinary to integrated: A study on the issues of science curriculum setting in junior high school*. China Light Industry Press.
Pigott, T. D., & Polanin, J. R. (2020). Methodological guidance paper: High-quality meta-analysis in a systematic review. *Review of Educational Research*, *90*(1), 24–46.
Putica, K. B., & Trivic, D. D. (2017). Improving high-school students' conceptual understanding and functionalization of knowledge about digestion through the application of the interdisciplinary teaching approach. *Journal of Baltic Science Education*, *16*(1), 123–139.
Richardson, J. S., & Showalter, V. (1967). Effects of a unified science curriculum on high school graduates. In V. M. Showalter (Author), *Effects of a unified science curriculum on high school graduates* (Order No. 6815377) [Doctoral dissertation, The Ohio State University]. *ProQuest Dissertations & Theses*.
Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies*, *37*(5), 525–559.
Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T., & Lee, Y. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, *44*(10), 1436–1460.
Schwab, K. (2017). *The fourth industrial revolution*. Crown Currency.
Schweingruber, H. A., Nielsen, N. R., & Singer, S. R. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. National Academies Press.
Shao, C. H. (2022). *The comparative research on junior-high students' subject competence of science in integrated and subject science curriculum* (Master's thesis, East China Normal University).
Shimwell, J., DeWitt, J., Davenport, C., Padwick, A., Sanderson, J., & Strachan, R. (2023). Scientist of the week: Evaluating effects of a teacher-led STEM intervention to reduce stereotypical views of scientists in young children. *Research in Science & Technological Education*, *41*(2), 423–443.
Shorten, A., Bratches, R., & Shorten, B. (2025). What is a meta-analysis? Evidence-based nursing, 28(2), 74–76.
Slavin, R. E., Lake, C., Hanley, P., & Thurston, A. (2014). Experimental evaluations of elementary science programs: A best-evidence synthesis. *Journal of Research in Science Teaching*, *51*(7), 870–901.
Slavin, R., & Smith, D. (2009). The relationship between sample sizes and effect sizes in systematic reviews in education. *Educational Evaluation and Policy Analysis*, *31*(4), 500–506.
Sun, D., Wang, Z. H., Xie, W. T., & Boon, C. C. (2014). Status of integrated science instruction in junior secondary schools of China: An exploratory study. *International Journal of Science Education*, *36*(5), 808–838.
Wang, Z., & Song, G. (2021). Towards an assessment of students' interdisciplinary competence in middle school science. *International Journal of Science Education*, *43*(5), 693–716.

Volume 10 Issue 58 (June 2025) PP. 1109-1125
DOI 10.35631/IJEPC.1058071

Weng, A. P. (2022). *A comparative study of junior high school students' scientific inquiry ability in the context of integrated and disciplinary science curricula* (Master's thesis, Shanghai Normal University).

Winarno, N., Rusdiana, D., Susilowati, E., & Afifah, R. M. A. (2020). Implementation of integrated science curriculum: A critical review of the literature. *Journal for the Education of Gifted Young Scientists*, *8*(2), 795–817.

Xie, L. X., Wang, X. J., & Guo, Y. Y. (2013). A comparative study of students' scientific literacy in junior high school integrated and disciplinary science curricula: Based on PISA test results. *New Curriculum Teaching: Electronic Edition*, *2*, 7.

Yildirim, N. (2022). Argumentation-based teaching in science education: Meta-analysis. *Education Quarterly Reviews*, *5*(2), 226–237.

Yilmaz, Z. A., & Batdi, V. (2021). Meta-analysis of the use of augmented reality applications in science teaching. *Journal of Science Learning*, *4*(3), 267–274.

Yıldırım, Y., & Şahin, M. G. (2023). How do different weighting methods affect the overall effect size in meta-analysis?: An example of science attitude in Türkiye sample. *International Journal of Psychology and Educational Studies*, *10*(3), 744–757.

You, H. S., Marshall, J. A., & Delgado, C. (2018). Assessing students' disciplinary and interdisciplinary understanding of global carbon cycling. *Journal of Research in Science Teaching*, *55*(3), 377–398.

Zhang, D., & Shen, J. (2015). Disciplinary foundations for solving interdisciplinary scientific problems. *International Journal of Science Education*, *37*(15), 2555–2576.

Zhu, C. P. (2017). *A comparative study on the scientific literacy of junior high school students under the influence of integrated and disciplinary science curricula* (Master's thesis, Nanjing Normal University).

Ziman, J. (2000). *Real science: What it is and what it means*. Cambridge University Press.