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Meta-Analysis: The Effectiveness of Differentiated Learning on Student Learning Outcomes in Science Subjects

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Abstract: The diversity of student learning styles is one of the internal factors that influences student learning outcomes. Differentiated instruction is a learning approach that emphasizes learning methods adapted to student's diversity. This study aims to examine the impact of differentiated instruction on student's learning outcomes in science education. This study is a meta-analysis that reviewed 10 articles Article were collected by Publish or Perish software with Crosseff as the database and the article selection used PRISMA. Data were analyzed according to the meta-analysis method, including the research bias test, effect size calculation of each article, heterogeneity test, and point estimation test. The result showed that the differentiated instruction in science learning gives a large effect on student's learning outcomes by the value of the effect size is 1,136. It means that the differentiated instruction learning has a significant and large effect on student learning outcomes in science learning. Based on this study, the differentiated instruction can be used as a recommendation for teachers to implement in order to improve student's learning outcomes. In addition, this study also expected to inspire other research to examine the characteristics of each other article to determine the factors that influence the result of differences in effect size of each article.

Keywords: Differentiated instruction; Learning outcomes; Meta-analysis

Introduction

Natural Science (IPA) is one of the subjects included in the independent curriculum. This subject is characterized by its emphasis on knowledge describing natural phenomena in the form of facts, concepts, principles, and laws, whose validity is verified through a series of scientific work processes, hereinafter known as the scientific method (Stamenkovic, 2023). The application of science learning can be viewed from three perspectives: science understanding, science process skills, and science attitudes. To determine students' level of science understanding, the results of science learning evaluations can be used. Student learning outcomes are a measuring tool for determining the achievement and mastery of the subject matter presented by teachers (Guo et al., 2020; Abdulrahaman et al., 2020). Student learning outcomes, or assessments, can be conducted through student tests. These assessments aim to determine students' level of understanding of science learning. In addition to determining students' level of competency achievement in science, teachers can also use these learning outcomes to determine the effectiveness of the learning methods or models they implement.

The use of appropriate learning methods is crucial for effective learning, especially since science is considered a complex subject. According to research by Shirazi (2017), student learning outcomes in science are still relatively low, and students perceive science as a mentally demanding subject that requires too much memorization. One way to address this issue is through the implementation of differentiated learning (Yantoro et al., 2023). Differentiated learning is learning that addresses the diverse characteristics of students (Goyibova et al., 2025). In practice, differentiated learning can be differentiated based on aspects of lesson

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content, processes, or meaningful learning activities, and assessments, also known as products (Langelaan et al., 2024; Muhab et al., 2024). Differentiated learning can be used as a solution because it is believed to accommodate the diversity of students' learning styles (Adare et al., 2023). The diversity of student learning styles is one of the internal factors influencing student learning outcomes (Suciani et al., 2022; Burke et al., 2024). With diverse learning styles, teachers are expected to implement appropriate learning to achieve positive results (Astiti et al., 2021; Holst et al., 2020; Pascu, 2024). Numerous studies have examined the effectiveness of differentiated learning in improving student learning outcomes (Hidayat et al., 2024; Dalila et al., 2022). These results indicate that differentiated learning is effective in improving student learning outcomes with varying effect sizes.

Most studies indicate that differentiated learning significantly impacts student learning outcomes in science subjects (Maryanti & Sartono, 2024; Agustav et al., 2025; Sitorus et al., 2022). Although these studies all show similar results, further analysis is needed to measure the overall effect of differentiated learning on student learning outcomes (Kahmann et al., 2022; Mukhibat, 2023). This measurement or analysis aims to confirm the conclusions of several previous studies, whether they are valid or not (Rahmawati et al., 2023). To analyze previous articles discussing the effectiveness of differentiated learning, researchers used a meta-analysis method. Meta-analysis is a type of review research that uses existing studies as data sources and is reviewed systematically and quantitatively to reach strong conclusions (Snyder, 2019; Santoso & Airlanda, 2022). Meta-analysis research uses statistical analysis techniques to process data from primary research to answer research questions regarding the overall effect of the reviewed studies (Lockett, 2025).

The purpose of meta-analysis research is to analyze publication bias that arises in studies with results that systematically differ from all other relevant studies. Based on this description, this study aims to investigate the effectiveness of differentiated learning on student learning outcomes in science subjects as a whole using meta-analysis.

Method

This study is a meta-analysis reviewing several research articles related to the effectiveness of differentiated learning on student learning outcomes in science subjects (Chaudhary & Singh, 2022; Wijaya et al., 2024). The articles used as samples were articles published between 2020 and 2025. The inclusion criteria included: experimental or quasi-experimental articles; articles examining the effectiveness of differentiated learning on student learning outcomes in science subjects; and articles containing data in the form of means, standard deviations, and sample sizes. The article search was assisted by Publish or Perish software with the Crosseff search database. The obtained articles then underwent a screening process using the PRISMA model. Articles were screened based on predetermined inclusion criteria and then analyzed, resulting in 10 articles ready for meta-analysis. The article screening process using the PRISMA method is presented in Figure 1.

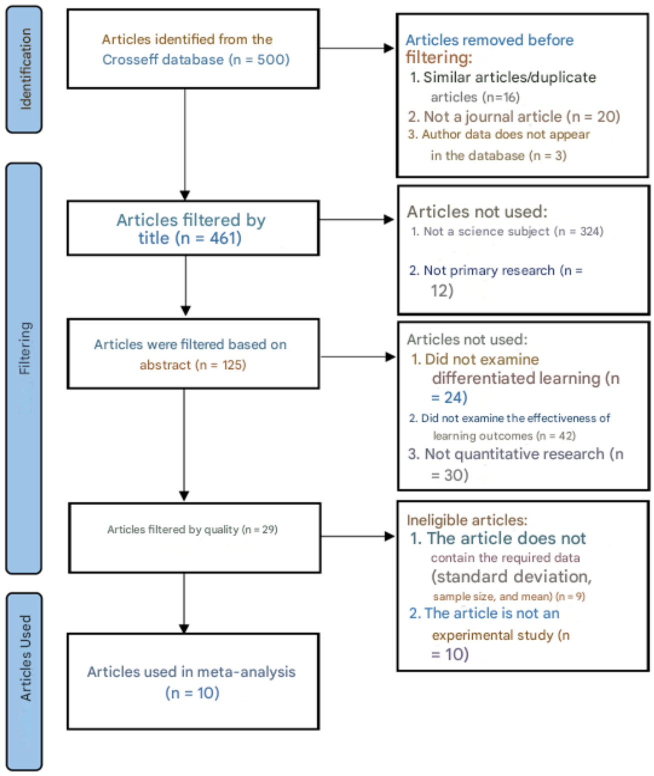

Figure 1. Article reduction flow using PRISMA

After obtaining suitable articles, the analysis process was carried out using Comprehensive Meta-Analysis (CMA) software, which consisted of statistical analysis for publication bias testing, effect size calculations, heterogeneity testing, and model estimation (Almalik et al., 2021; Lin et al., 2018).

Result and Discussion

Based on article selection using the PRISMA method, 10 primary articles were obtained for further analysis using meta-analysis procedures. These articles are presented in Table 1. After all articles were collected, the statistical data extraction process was carried out, which is presented in Table 2.

Table 1. List of Articles Used in the Research

Title	Writer	Year	Method
Pembelajaran Berdiferensiasi Berbasis Technological Pedagogical and Content Knowledge (TPACK) Meningkatkan Hasil Belajar IPAS Kelas IV	Dheanita Rachmawati, Putri Yanuarita Sutikno	2024	Quasi-Experiment
Pengaruh Pembelajaran Berdiferensiasi Terhadap Pemahaman Siswa Pada Pembelajaran IPAS Kelas IV Sekolah Dasar	Faizal Agustav, Dwi Cahaya Nurani, Esti Susiloningsih	2025	Quasi-Experiment
Efektivitas Model Pembelajaran Discovery Learning dan Problem Solving terhadap Hasil Belajar IPA pada Siswa Sekolah Dasar	Farhan Aldino Santoso, , Gamaliel Septian Airlanda	2022	Quasi-Experiment
Efektivitas Strategi Card Sort dalam Pembelajaran IPA pada Siswa Kelas IV SD Muhammadiyah 10 Palembang	Piko Priando, Dian Nuzulia Armariena, Rury Rizhardi	2023	Experiment
Efektivitas Penerapan Pembelajaran Berdiferensiasi Terhadap Hasil Belajar Siswa Pada Mata Pelajaran Ipas Kelas IV SDN 57 Pepabri Kota Palopo	Vivi Adelianty, Amir Pada, & Widya Karmila Sari Achmad	2024	Experiment
Efektivitas Model Pembelajaran Berdiferensiasi Terhadap Hasil Belajar Ipa Rantai Makanan Siswa Kelas 5 SD Negeri 2 Bandar Sakti	Pandi Fajar Kurniawan, Ryan Dwi Puspita	2025	Quasi-Experiment
Pengaruh Strategi Pembelajaran Berdiferensiasi terhadap Hasil Belajar Peserta Didik Kelas VIII SMP Negeri 2 Manduamas	Parlindungan Sitorus, Riossally Marselina Tumanggor, Mula Sigiro, Eka Notasya Simanullang, Indah Septa Ayu Laia	2022	Quasi-Experiment
Pengaruh Pembelajaran Berdiferensiasi Gaya Belajar Terhadap Hasil Belajar IPA Pada Siswa Kelas 5 Sekolah Dasar	Anik Nawati, Dina Kurniastuti, Ika Dyah Kumalasari, Dewi Wulandari, dan Ana Fitrotun Nisa	2023	Quasi-Experiment
Pengaruh Pembelajaran Berdiferensiasi Terhadap Hasil Belajar Siswa Padamata Pelajaran IPAS Di Kelas IV SD Swasta Budi Mulia Binjoharatahun Pembelajaran 2023/2024	Iskawati Maria Tumanggor, Antonius Remigius ABI, Bogor Lumbanraja, Dyan Wulan Sari HS, Ester Julinda Simarmata	2024	Experiment
Efektivitas Penggunaan Strategi Pembelajaran Berdiferensiasi Terhadap Hasil Belajar IPA di Sekolah Dasar	Alisa Maharani, Azaz Akbar, Fitriani B	2025	Quasi-Experiment

Table 2. Summary of Statistical Data Extraction

Article Code	Statistical Data					
	Control Group			Experimental Group		
	N	Mean	SD	N	Mean	SD
MA1	27	65.93	8.55	27	86.85	11.02
MA2	21	86.05	9.63	21	92.71	7.57
MA3	25	82.44	6.25	25	89.50	10.15
MA4	26	66.38	12.08	30	77.90	10.85
MA5	20	57.75	18.95	20	81.50	9.61
MA6	20	75.50	7.91	20	84.60	6.56
MA7	30	58.33	13.48	30	65.67	12.37
MA8	28	66.07	18.87	28	80.36	15.63
MA9	22	59.09	14.36	22	82.00	8.44
MA10	14	61.43	15.74	15	75.33	13.43

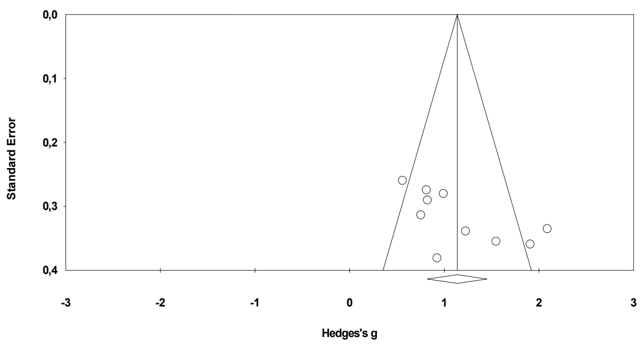

Figure 2. Bias test with funnel plot

The data presented in Table 2 then underwent statistical analysis, testing for publication bias using a funnel plot and the fail-safe N (FSN) test. The funnel plot shows the distribution of effect sizes for each research article. The funnel diagram is shown in Figure 2.

Based on the funnel plot results presented in Figure 2, it was found that each article was distributed on the left and right sides, but the distribution was visibly asymmetrical, making it somewhat difficult to interpret. Therefore, another bias test was necessary using the fail-safe N test, with the results presented in Table 3.

Table 3. Results of the Classic Fail-Safe N Test

	Classic Fail-Safe N
Z value (Z-value) for	11.34281
p value (p-value)	0.00000
Alpha	0.05000
Z is for alpha	1.95996
Lots of data	10.00000
Fail-Safe Value N	325.00000

The FSN test results in Table 3 show a p-value of 0.000. This value is lower than the alpha value (p-value <0.05), thus concluding that the effect size determined for each article under review is robust against publication bias (Nuijten et al., 2020; Afonso et al., 2024; Bartoš et al., 2023). The next step is to test the effect size for each article using the Hedges'g equation presented in Table 4.

Table 4. Effect Size of Each Article

Code	Effect Size (Hedges'g)	Description	Lower Bound	Upper Limit
MA1	2.09	Very Large	1.43	2.74
MA2	0.75	Medium	0.13	1.36
MA3	0.82	Large	0.25	1.39
MA4	0.99	Large	0.44	1.54
MA5	1.54	Very Large	0.85	2.24
MA6	1.22	Large	0.56	1.89
MA7	0.56	Medium	0.05	1.06
MA8	0.81	Large	0.27	1.35
MA9	1.91	Very Large	1.20	2.61
MA10	0.92	Large	0.17	1.67

Table 4 shows that each article has a diverse effect size. Three articles have very large effect sizes, namely MA1, MA5, and MA9; five articles have large effect sizes, namely MA3, MA4, MA6, MA8, and MA10; and two articles have medium effect sizes, namely MA2 and MA7. For more clarity, the effect size for each article is illustrated based on the forest plot shown in Figure 3.

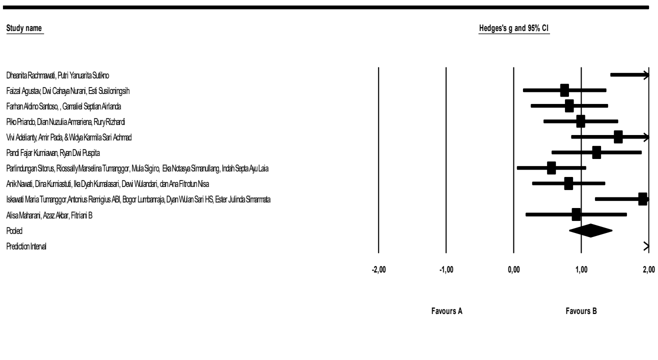

Figure 3. Effect size of each article in a forest plot

Figure 3 shows that the effect sizes for all studies are to the right of zero (positive). This indicates that all articles have a positive effect on improving student learning outcomes. The next step in data analysis was a heterogeneity test and an estimation model to obtain the overall effect size of the study. The results of the heterogeneity test are presented in Table 5.

Table 5. Heterogeneity Test

Heterogenitas			
Q-value	df(Q)	p-value	I-squared (%)
23.408	9	0.005	61.552

The heterogeneity test results were interpreted based on the Q-value and p-value statistics. Table 5 shows a Q-value of 23.408, and a Q-table value of 16.919 with 9 degrees of freedom (df) at a significance level of 0.05. This indicates that the Q-value is greater than the Q-table. Furthermore, a p-value of 0.005 was obtained at a 95% confidence level (p-value <0.05). Both results indicate significant heterogeneity across the studies. The heterogeneity of the effect size distribution across the studies can also be seen from the I-squared value. Table 5 shows an I-squared value of 61.552%, indicating high effect size heterogeneity. This indicates that the effect size distribution across the articles is heterogeneous, and a random effects model was used to determine the combined effect size (McKenzie & Veroniki, 2024; Fernández-Castilla et al., 2020; Holzmeister et al., 2024; Stanley et al., 2022). After selecting the overall effect size determination model, the results of the effect size calculation for all articles based on the random effects model are presented in Table 6.

Table shows that the overall effect size of the 10 articles analyzed was 1.13, with a 95% confidence interval. This figure indicates that differentiated learning has a significant effect on improving student learning outcomes. Furthermore, the P-value in Table 6 is 0.000, lower than the confidence interval (P-value = 0.000 < 0.05). This indicates that the implementation of differentiated learning has a significant effect on improving student learning outcomes in science (Mohsenipouya et al., 2024; Darling-Hammond et al., 2020; Zurita-Alarcón et al., 2024). Based on the data presented above, a meta-analysis of the implementation of differentiated learning on science learning outcomes yielded an effect size of 1.136, categorized as significant. This finding suggests that learning using a differentiated approach can significantly improve student learning outcomes (Ariesta, 2025; Subandiyah et al., 2025; Haelermans, 2022). This is consistent with previous research showing that differentiated learning has a significant positive impact on improving student learning outcomes, as it can improve academic performance by an average of 15% to 25%.

Table 6. Effect Size Based on the Random Effect Model

Estimation Model					95% Confidence Interval	
	N	Z	P	Effect Size	Lower Limit	Upper Limit
Random effect	10	7.08	0.000	1.13	0.152	2.12

Furthermore, differentiated learning is considered effective in improving academic success and is relevant for use in various fields of educational study (Pozas et al., 2023; Oktoma et al., 2025; Taş & Minaz, 2024). Other studies also show that differentiated learning has a significant positive effect on student learning outcomes across various grade levels, subject matter, educational levels, research areas, and application types (Saleh et al., 2025; Yunita et al., 2023). This means that differentiated learning is effective in various situations to improve student learning outcomes because it provides varied learning experiences that can accommodate the diversity of learning styles possessed by students (Shaidullina et al., 2023; El-Sabagh, 2021; Deng et al., 2022).

Conclusion

Based on the analysis of 10 articles related to the effectiveness of differentiated learning on science learning outcomes, it can be concluded that differentiated learning has a large and significant effect on improving student learning outcomes in science subjects. Through the results of this study, teachers are expected to use differentiated learning with a combination of learning models that focus on student activities as an alternative to improve learning outcomes and science skills. In addition, future researchers are expected to be able to examine the characteristics of each other study to determine the factors that influence the results of differences in effect size in each article.

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Author Contributions
I G. A. A. Dyah Armayanti as principal researcher; I W. Redhana and I N. Tika reviewed and edited the manuscript. All authors have approved the final published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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