Impact of Innovative Learning in Mathematics and Natural Sciences on Student Learning Achievements: A Meta-Analysis

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	ABSTRACT
ARTICLE INFO *Article history:* Received December 28, 2022 Revised March 25, 2023 Accepted May 11, 2023	This study was to analyze the impact of innovative learning on student learning achievement in Mathematics and Natural Sciences from 2014 until 2021. The data collection method used in this study is a meta-analysis, where the researchers would search related articles through *Google Cendekia* (*Google Scholars*) and *ScienceDirect*. This research obtained 227 articles. All selected articles cover the research conducted in schools, from elementary to high school level. These articles will be analyzed in several steps: (1) determining research domains that will be summarized; (2) selecting the types of collected publications; (3) collecting results of studies or literature; (4) listing research data; (5) calculating the effect size of each source or study. After passing this five-step process, 21 articles that discussed how innovative learning in mathematics and natural sciences affects student achievement were selected. These articles will be analyzed using the JAMOVI application. The results found an average difference, ranging from -0.99 to 3.10.
	Keywords: *Innovative Learning, Natural Sciences, Learning Achievements*

INTRODUCTION

A teacher is a central figure in achieving the goals of education (Engels et al., 2021; Reinius et al., 2022; Zeinstra et al., 2023). The teacher profession is also stated in the Law of the Republic of Indonesia No. 14 Year 2005 about Teachers and Lecturer, where Article (10) Paragraph 1 stipulates that teachers' competencies include pedagogical, personality, social, and professional competence gained through professional training.

As one of said four competencies, pedagogical competency relates to the teacher's capability to understand their students, plan and conduct learning activities, evaluate student learning achievements, and assist them in developing their potential (Bøe et al., 2022; Karlen et al., 2023) . A sub-competency in the pedagogical area is the ability to plan learning activities and to understand the educational basis for conducting such activities. It includes selecting the most appropriate learning theory and determining the most effective learning strategy to facilitate the students in achieving their learning goals or developing their potential for their future (Asrial et al., 2019; Sulistyawati, 2018; Syahrial et al., 2019; Mohammadpour & Maroofi, 2023).

Learning is a two-way communication between a teacher and the students, where intense and directed information transfer occurs to achieve a particular target that is set beforehand (Al-Tabany, 2017). In this era, the expected target involves a wide range of skills that a student should achieve, including knowledge, meta-cognitive communication, critical and creative thinking, effective communication, and collaborative skills (Fatmawati et al., 2019). Presumably, innovative learning can bring a positive impact on student achievement.

A professional teacher will teach innovatively. Monotonous learning will not motivate students and reduce their participation in the learning activity. Ideally, expectedly gaining improving results of students learning achievement, a professional teacher should employ various innovative learning methods. Thus, this research aims to disclose some impacts of varied innovative learning methods in both mathematics and natural sciences subjects from Elementary to senior high school. Innovation is one of teachers' professional competencies. Additionally, modern teachers will prepare some innovations to prevent students from getting bored with studying. An old-fashioned teaching-learning activity through long and dull lectures will bore the students and, as a consequence, makes them passive (Ratnawati, 2021). An example of innovative learning is by changing learning methods. Low achievement in mathematics tends to be caused by ineffective and less varied methods suitable for the topics (Khotimah, 2017). Aside from methods, learning media also affects student achievement. It is closely related to the teaching and student's learning style. Nonetheless, a good teacher will adapt to the student's learning styles and assist them with appropriate learning media (Dewi Astiti et al., 2021). Moreover, learning models are also vital in improving student achievement, where varied learning models for mathematics and natural sciences positively impact student achievement (Khotimah, 2017; Suriati, 2019; Yanto & Juwita, 2018) dan (Samitra et al., 2018). Another way to apply innovative learning is by varying learning media. It is in line with some studies on learning media, where different media are proven effective in improving student achievement (Aisyah et al., 2018; Azis et al., 2018; Oktarina et al., 2021). For example, innovative learning can use the augmented reality mode (Estapa & Nadolny, 2015).

So far, numerous research on innovative learning techniques have been conducted, and the results are published in national and international journals. Unlike the other preceding studies on this specific topic, this study is a meta-analysis that observes how innovative learning affects student achievement in mathematics and natural sciences subjects. For these subject teachers, innovative learning application is essential in arranging the lesson plan and executing the teaching-learning activity in class. From this study, the significance of innovative learning methods through their success rate analysis in various educational levels from elementary to high school will be able to be drafted.

METHOD

This study uses a mean meta-analysis design by calculating the effect size of the random-effects model. A meta-analysis is a systematic synthesis of diverse research on particular topics and an attempt to collect relevant research data (Valentine et al., 2009). In other words, it can also be considered an analysis-analysis. A meta-analysis is a study that focuses on the literature on similar topics and is used to present a statistical conclusion. The result of this type of analysis is expected to complement previous research data and is used to compare them.

The data collection method in this kind of analysis is documentation, which is done by gathering research data on similar topics. As for this study, data collection is done by gathering articles using Google Scholar, a search engine that links to numerous journal websites and indexing agencies. It strategically gathers a wide range of data that can represent global conditions comprehensively and avoid bias. In this study, the collected documents are in the form of articles taken from various national journals. This study population consists of all documents discussing the impact of innovative learning in mathematics and natural sciences on student achievement.

A purposive sampling technique is used to select the samples of this study. They must be appropriate for this topic and meet several requirements. (1) articles must be written by teachers or lecturers; (2) published within 2014 up to 2021; (3) using a quantitative approach; (4) focusing on the impact of innovative learning in mathematics and natural sciences on student learning achievement in elementary, secondary, and high school levels. Of 227 articles with similar problems and results, 18 documents are considered eligible to be the samples of this study. Meanwhile, the remaining documents are excluded due to several factors, including the absence of a control group, inappropriate learning method (using action research type), and unstated pre-test and post-test average values comprehensively. The determination of the samples is illustrated in Figure 1 below.

Figure 1. Scheme of Determining the Number of Samples
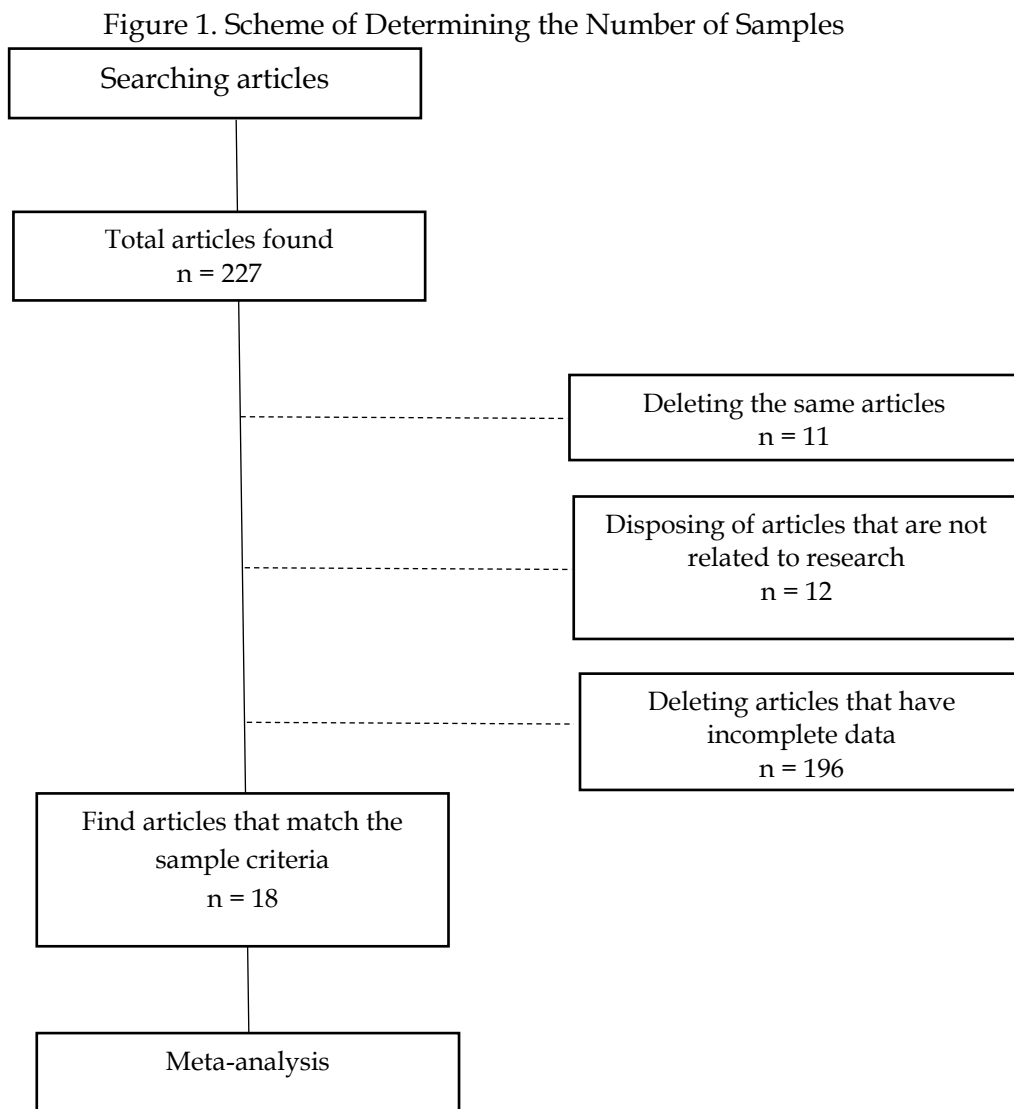
This study used quantitative data analysis using Microsoft Excel and JAMOVI (Şahin & Aybek, 2019; Bartlett & Charles, 2022). These applications will calculate the effect size of each study or the overall effect size and aggregate. Furthermore, Heterogeneity Statistics and Fail-Safe N of Studies are also applied

RESULT AND DISCUSSION

This study primarily focused on the research on the impact of innovative learning in mathematics and natural sciences on student learning achievement, where it compares the control group and the experimental group. According to the sample size, mean, and standard deviation, the researchers can formulate d and variance (v), as presented in Table 1.

Table 1. Summary of Research Data, d value, and v value

No	Authors	Experimental			Control			d	variance
		N	Mean	SD	N	Mean	SD		
1	(Erniwati et al., 2014)	30	61.37	9.28	30	43.27	12.92	1.6091	0.0882
2	(Prayogi et al., 2014)	27	74.41	10.25	27	69.26	9.59	0.5189	0.0766
3	(Wahyu et al., 2016)	30	75.86	9.826	29	39	16.26	0.012	0.26
4	(Jauhari, 2016)	34	70.24	11.91	35	57.6	9.26	1.1871	0.0682
5	(Wahyuni & Jailani, 2017)	30	75.47	13.11	34	68.53	13.62	0.5185	0.0648
6	(Ariani, 2017)	25	83.41	12	25	75.73	8.84	0.729	0.292
7	(Samitra et al., 2018)	26	79.88	6.11	26	72.19	7.49	1.4131	0.0961
8	(Gumay & Bertiana, 2018)	30	80.45	12,25	29	59.48	11.28	1.859	0.1007
9	(Azis et al., 2018)	39	77.17	11.3	39	70.93	9.67	0.5933	0.0535
10	(Khotimah et al., 2018)	32	46.28	34.53	32	16.53	15.32	1.048	0.295
11	(Suriati, 2019)	27	99.11	3.2	22	78.9	18.9	1.572	0.328
12	(Artini et al., 2019)	31	73.42	14.22	31	64.26	14.64	0.6347	0.0678
13	(Selviani, 2019)	34	85.2	5.45	34	78.88	9.31	0.8285	0.0639
14	(Nazliah et al., 2019)	38	74,342	8,068	36	69,58	10,648	0,506	0,0558
15	(Darmawan, 2020)	34	85.21	7.147	36	76.72	8.077	1.1113	0.066
16	(Rini, 2020)	35	74.43	-8.906	35	68.23	7.681	0.7455	0.0611
17	(Oktarina et al., 2021)	21	76.14	9.634	22	71.34	10.632	0.4726	0.0957
18.	(Wajdi, 2021)	20	86.15	5.967	20	65,25	11.521	2.3053	0.1664

Note: i) M = mean of each data presented in the research sample; ii) n = number of data presented in the sample analysis; iii) SD = standard deviation, as shown by the sample; iv) d (Esg) = effect size as a quantitative index that is used to summarize the results in a meta-analysis. The effect size represents the extent of the relationship between variables in each research. In this study, the effect size illustrates the impact of innovative learning in mathematics and natural sciences on student achievement; v) v (SEg) = Standard Error, the value that is used as the foundation to calculate the actual effect size intervals.

Heterogeneity Statistics

The results of the Heterogeneity test or Heterogeneity Statistics were analyzed using the JAMOVI application. The results are presented in Table 2.

Table 2. Heterogeneity Statistics

Tau	Tau²	I²	H²	R²	df	Q	p
0.428	0.1835 (SE= 0.0975)	67.21%	3.050	.	17.000	47.998	< .001

The results show that the 18 effect sizes analyzed in this study are heterogeneous (Q = 47,998, p < 0,001). In other words, the analyzed studies came from a different population.
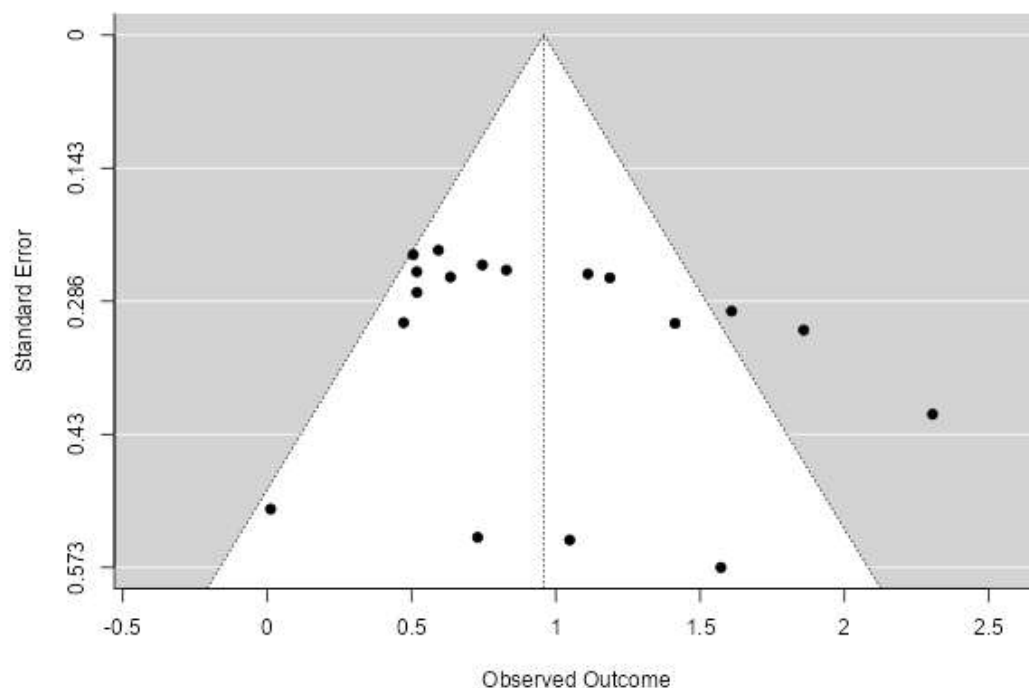
Publication Bias

There are three ways to determine whether or not the studies have publication bias: Funnel plot, Egger's test, and Fail-safe N.

Funnel Plot Analysis

The results of the Funnel plot analysis can be seen in Figure 2.

Figure 2. Funnel plot

Seeing the effect size distribution of the 18 studies shown by the funnel plot above, the data cannot be straightforwardly considered symmetrical. In other words, whether or not this meta-analysis has a bias cannot be fully guaranteed.

Therefore, statistical analysis using Egger's test and Fail-Safe N must be applied to assess whether or not the funnel plot is symmetrical.

Table 3. Publication Bias Assessment

Test Name	value	p
Fail-Safe N	1112.000	< .001
Kendalls Tau	0.333	0.057
Egger's Regression	0.890	0.374

Note. Fail-safe N Calculation Using the Rosenthal Approach

As seen in Table 3, the Egger's test value (Egger's Regression) was 0,890 and p=0,374. Since p > α, where 0,374 > 0,05, the funnel plot shown in Figure 2 is considered symmetrical, although it does not seem like it in the diagram (Rothstein, 2008). Hence, there is no publication bias indicated in the 18 samples. From that Funnel plot, three studies come from outside the curve, which are Wajdi and firdaus (2021), Gumay And Bertiana (2018) and Erniwati (2014).

Subsequently, the Fail-Safe N value of 1112 was obtained. This value was > than 5(k) + 10 as much as (5 x 18) + 10 = 100. Based on this calculation, it is assumed that there is no publication bias found in this meta-analysis (Rosenthal, 1979).

Random-effects Model

The results of the Random-effects Model are presented in Table 4 below.

Table 4. Random-Effects Model (k = 18)

	Estimate	se	Z	p	CI Lower Bound	CI Upper Bound
Intercept	0.959	0.127	7.55	< .001	0.710	1.208
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Note. Tau² Estimator: Restricted Maximum-Likelihood

The random-effects analysis for 18 analyzed studies acquired the Estimate value of 0,959, with p < 0,001 (α=0,05 {CI=0,710 to 1,208}). It shows a positive-significant correlation between innovative learning and student achievement in mathematics and natural sciences subjects. However, the impact of this approach in mathematics and natural sciences on student achievement is considered low. It can be identified from the *se* value (summary effect), which was only 0,127 (Cohen, 1988). Meanwhile, the data distribution of the 18 analyzed studies can be seen in the Forest plot below

Figure 3. Forest plot
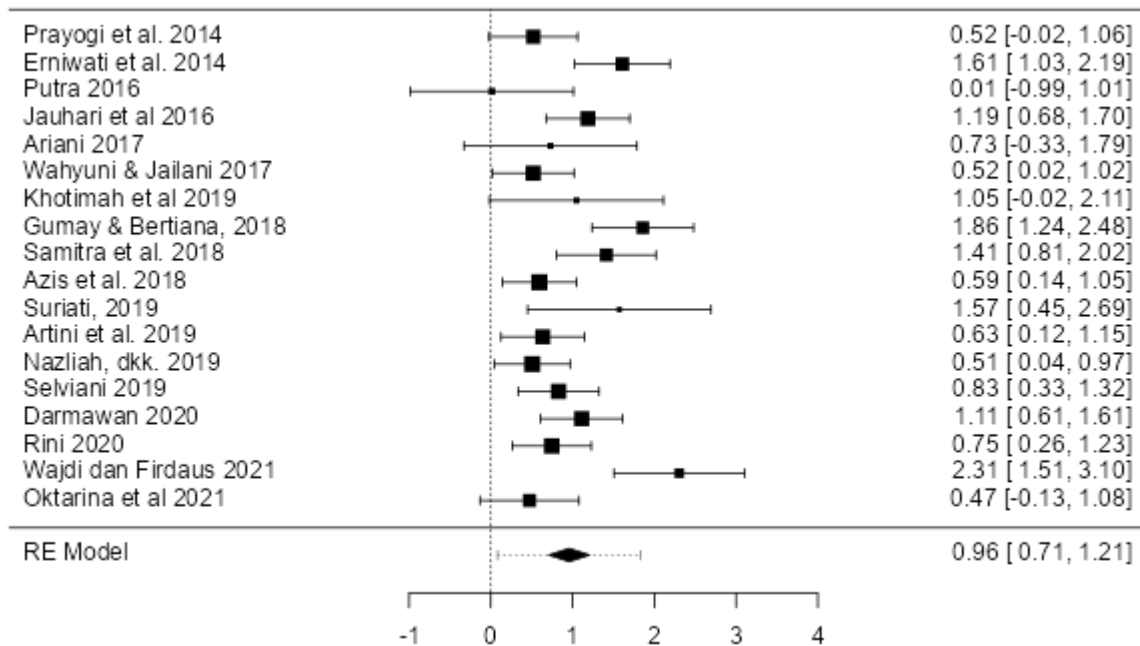
As seen in Figure 3 (Forest Plot), the effect size of the 18 analyzed studies varied from -0,99 to 3,10.

Figure 3 (the forest plot) above revealed the size and direction of each research and its aggregate. According to 18 analyzed researches, the overall results of the research's effect size were on the right side. Similarly, the mean or its aggregate of the effect size was in the same part, which was in number 1. Also, in figure 3, it can be concluded from all of the results of the analyzed research that the grade in the post-test was higher than the grade in the pre-test (Djidu & Kartianom, 2018:41). A research conducted by Putra (2016) regarding "Mathematics Learning Using Accelerated Learning Method to Improve Adaptive Rationale Ability of Junior High School Students" was research having the smallest sample size and had a minimum threshold of the smallest effect size (minus 1). Meanwhile, the research performed by Wajdi and Firdaus (2021), entitled "Impacts of the Implementation of Course Review Horay Learning Model to Students' Study Results of Biology in the Virus Material", depicted that though it has a small sample size, the maximum threshold of the effect size is the biggest.

The research was to analyze various innovative learning methods in both mathematics and natural sciences subjects and it was neither only to observe some impacts of the certain use of learning media (Surata et al., 2020; Khairani et al., 2019; Khomaidah & Harjono, 2019), nor learning model/methods (Handayani & Koeswanti, 2021; Anugraheni, 2018; and Parwata, 2021; Gracia & Anugraheni, 2021; Zhan et al., 2022). The meta analysis of this research presented descriptive-quantitative data, not only descriptive-qualitative (Budiarto & Artiono, 2019;). In general, the research was to view impacts and not analyze the relationship between variables (correlation) (Utami, 2017; Adiputra & Mujiyati, 2017). The analysis, conducted in 18 study results, shows that all innovative learning methods in mathematics and natural sciences subjects had positive impact to students learning achievement in both subjects. Therefore, respective teacher expectedly established the innovative learning of mathematics and natural sciences subjects at school.

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Though this research could explain some positive impacts of the innovative learning method in mathematics and natural sciences on students learning achievement, some limitations still existed. Firstly, the analyzed articles were derived from the searching results in Google Scholar so that it limited for generalization. Secondly, those analyzed articles were learning innovations in mathematics and natural sciences conducted in Indonesia. Then, the results of analysis would be different if the sources of the analyzed articles involved international-scaled research. Lastly, the analyzed articles had long span of periodization, which was 2014, while, currently, Indonesia has applied the "merdeka" curriculum, definitely having new learning innovations in mathematics and natural sciences.

The analysis of the results of the research related to learning innovations in mathematics and natural sciences after the pandemic was beneficially to conduct. During the Covid-19 pandemic outreaching Indonesia and the world, all countries made some innovations to anticipate direct contact in classroom due to the limitation of the Covid-19 plague. Also, the massive development of learning technologies became the only long-distance learning media. The learning during the Covid-19 pandemic was conducted via online using various digital learning platforms. It was reported by the research conducted by (Barry et al., 2019; Benavides-Varela et al., 2020; Hillmayr et al., 2020; Stecuła & Wolniak, 2022). This event occurred around the globe, so that the learning innovations in the pre- and post-Covid 19 pandemic had significant differences. Indeed, some countries had failed to anticipate the spread of the Covid-19 pandemic and their education system were disrupted. Hence, the meta analysis would provide information related to the implementation of varied innovations in education of each country.

CONCLUSION

Based on the Fail-Safe N value, Egger's Regression value, and Funnel Plot data, no bias is indicated in this meta-analysis. In conclusion, innovative learning for mathematics and natural sciences can improve student achievement in these two subjects. However, this meta-analysis only focuses on the studies about innovative learning on student achievement in mathematics and natural sciences subjects from Indonesian research. It would be much more enticing to analyze international studies as well. Developing further research on different school subjects besides mathematics and natural sciences will also be beneficial. More expanded research that will correlate student achievement with other variables, such as gender, motivation, and school-house distances, may also be conducted in the future.

AUTHOR CONTRIBUTION STATEMENT

NZ contributes to searching relevant articles and script writing. SS contributes to methods application and data analysis.

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