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Effectiveness of STEM-Based Mind Mapping Learning Model to Improve Students' Science Literacy in the Era of Revolution 4.0

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Abstract: This study aims to analyze the size effect of the STEM-based mind mapping learning model to increase students' scientific literacy in the revolutionary era 4.0. This type of research is meta-analysis. The research samples came from 15 national and international journals published from 2018-2023. The method for selecting this meta-analysis research data is through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Search for data sources through Google Scholar, Wiley, Eric and ProQuest. Data source collection techniques are direct observation and documentation through online databases. Data analysis is a quantitative analysis by calculating the effect size, standard error and average value with the help of the JSAP application. The results showed that from this study it could be concluded that the combined effect size value was (d = 1.30; p < 0.05) high criteria. These findings explain that STEM-based mind mapping models are more effective in improving scientific literacy skills in the 4.0 revolution era than conventional learning models. The STEM-based mind mapping learning model provides a new breakthrough in the world of educational technology.

Keywords: Learning; Mind mapping; Science literacy; STEM; Revolution 4.0

Introduction

Science literacy is an ability that students must have related to science in the era of the industrial revolution 4.0 (Alatas & Fauziah, 2020; Kristiantari et al., 2022; Lee et al., 2020; Özkan, 2021). Science literacy plays an important role for students in solving problems (Ichsan et at., 2023; Sutiani et al., 2021; Spitzer & Fraser, 2020; Laslo & Baram-Tsabari, 2021). Furthermore, science literacy skills become the standard of student success in the education curriculum in Indonesia (Raehanah et al., 2020; Adiwiguna et al., 2019). Students who have science literacy skills are able to apply learning materials in everyday life (Vandegrift et al., 2020; Islami & Nuangchalerm, 2020; Şadoğlu, 2018; Cansiz & Cansiz, 2019). Stefanski et al. (2019) students who have science literacy skills are able to think critically, creatively, logically and systematically.

But in reality, the science literacy of Indonesian students is still very low. Based on the results of the 2018 Programmer for International Student Assessment (PISA) research conducted by the Organization for Ecomomic Cooperation and Development (OECD), the science literacy skills of Indonesian students obtained a score of 396, ranked 71 out of 78 members (Rahman et al., 2023; Oktarina et al., 2021; Aiman et al., 2020; Avikasari et al., 2018; Suharyat et al., 2022). The low science literacy skills of students are influenced by the teacher-centered learning process, the low ability of students to explain scientific phenomena and the lack of

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student learning resources (Anggreni et al., 2020; Mundzir et al., 2017; Karataş et al., 2022; Turgut & Yakar, 2020). Research results Jufrida et al. (2019) the low science literacy skills of students are due to the learning process that only trains students in understanding the content and subject matter. Furthermore, the selection of learning models and methods that are not sufficient to develop students' science literacy skills (Pujiastutik, 2018; Suhaimi et al., 2022; Cahyana et al., 2019; Razak et al., 2021; Taha & Cobanoglu, 2021).

Mind mapping is a learning model that can foster students' science literacy skills in learning (Wiraputra et al., 2023). Mind mapping is a learning model that can foster student activeness and motivation in learning (Ma'ruf et al., 2019; Pridadi & Susilana, 2021; Leontyeva, 2021). Research results Gavens et al. (2020) the mind mapping model helps students remember information faster, thus stimulating students' science literacy in learning. Mind mapping helps students learn more creatively and have a strong imagination in learning (Balim, 2013; Sari et al., 2016; Takaria & Palinussa, 2020; Hariyadi et al., 2018; Sezer, 2022).

Furthermore, STEM-based mind mapping learning can improve students' critical thinking skills in learning (Nyoman & Wati, 2021; Suharyat et al., 2022; Hacioglu, 2021; Baran et al., 2021). STEM is a learning approach that combines science technology engineering and math in learning activities (Topsakal et al., 2022; Aminah, 2022). Research results Afriana et al. (2016) STEM-based learning can foster science literacy and student learning outcomes. The STEM approach helps students more easily apply science and technology to achieve learning objectives (Pahruddin et al., 2019; Asigigan et al., 2021; Zengin et al., 2022).

Research results Arulselvi (2017) states that the mind mapping model is effective for increasing student motivation and learning outcomes in the learning process. Ruhama (2021) the mind mapping model helps develop students' thinking patterns according to how the students' brains work. Research results Yıldızlı et al. (2020) the application of mind mapping model in learning can encourage students' higher order thinking skills. Research Batdi (2017) stated that the mind mapping learning model has an influence in shaping students' attitudes, character and motivation. Research results Topsakal et al. (2022) STEM-based learning can improve students' science literacy. But in reality, there are many studies on mind mapping but there are still few studies on the effect of STEM-based mind mapping learning on students' science literacy. Based on the problem, this research aims at STEM-based mind mapping learning model to improve students' science literacy in the era of revolution 4.0.

Method

Design Research

This study is a type of meta-analysis research. Meta-analysis is a study that analyzes studies that can be statistically analyzed (Chen et al., 2022; Razak et al., 2021; Suharyat et al., 2022; Kim & Choi, 2021). This meta-analysis aims to determine the effect of STEM-based mind mapping learning model to improve students' science literacy. According to Borenstein et al. in (Badawi et al., 2023), The steps to conduct a meta-analysis consist of 1) determining inclusion criteria; 2) collecting data as well as providing data coding and 3) Data analysis.

Inclusion Criteria

The inclusion criteria in this meta-analysis study are 1) Research comes from national and international journals published from 2018-2023; 2) The type of research uses experimental or quasi-experimental methods; 3) The research has two classes, namely the model experimental class and the control class; 4) The research presents complete data to calculate effect size.

Literature Collection and Screening

The literature collection process in this meta-analysis adapts to the predetermined inclusion criteria. Collection of research literature through google scholar, ERIC, Wiley, ScienceDirect, ProQuest and Plos ONE databases. With keywords namely "the influence of STEM-based Mind Mapping learning model" and "Mind Mapping Learning Model" and "Students' science literacy". Next, the data were collected and screened. The screening process was carried out by means of identification, screening, eligibility and inclusion. From the results of the screening process, 12 studies were collected that were used as data sources for the meta-analysis. However, there were studies that had control classes resulting in 14 effect sizes being analyzed.

Coding

In this meta-analysis data coding includes education level, publication year, and sample size. The results of data coding can be seen in Table 1.

Table 1. Meta-analysis Data Coding Results

Content Coding		Frequency	Percentage (%)
Education Level	SD	4	30.76
	SMP	6	46.15
	SMA	4	23.07
Year of Publication	2018-2020	5	38.46
	2021-2022	9	69.23
Sample Size	Under 25	6	45.12
	Above 25	8	61.53

Data Analysis

Data analysis in this study is quantitative statistical analysis. Data analysis in meta-analysis consists of 1) calculating the effect size value of each study; 2) Conducting heterogeneity tests of each study; 3) Analyzing moderator variables and 4) determining publication bias (Borenstein et al., 2010). Furthermore, data analysis with the help of JSAP application. The effect size follows Cohen's size (2018). The Q parameter is used to test the heterogeneity of the study. The heterogeneity test serves to determine the estimation model for calculating the combined effect size. Furthermore, the determination of research publication bias using the Fail Safe N (FSN) approach described by (Borenstein & Hedges, 2009; Borenstein et al., 2010).

Table 2. Criteria Effect Size Cohen's (Suyantiningsih et al., 2023; Suryono et al., 2023; Sun, 2015)

Effect Size	Criteria
0.00 < ES ≤ 0.19	Ignored
0.19 < ES ≤ 0.49	Low
0.49 < ES ≤ 0.79	Medium
0.79 < ES ≤ 1.29	High
ES > 1.29	Very High

Result and Discussion

Results

In the meta-analysis that has been carried out, the initial stage is to determine the effect size of each study. The results of the calculation of the effect size of each study can be seen in Table 3.

Table 3. Effect Size of Research

Journal Code	Years	Effect Size	95 % Confidence Interval	
			Lower	Upper
A1	2021	0.77	0.23	1.12
A2	2022	2.17	1. 29	2.98
A3	2021	0.92	0.40	1.57
A4	2018	0.60	0.37	0.77
A5	2019	1.33	1.03	1.82
A6	2019	0.85	0.59	1.04
A7	2020	0.38	-0.57	0.48
A8	2020	1.40	0.79	1.72
A9	2023	0.87	0.52	1.30
A10	2021	0.58	0.26	0.92
A11	2023	0.96	0.47	1.22
A12	2018	0.82	0.69	1.09
A13	2022	1.10	0.87	1.40
A14	2019	0.84	0.31	1.11

Table 3 shows that of the 14 studies analyzed, the lowest effect size was 0.38 with a lower limit of -0.57 and an upper limit of 0.48 while the highest effect size was 2.17 with a lower limit of 1.29 and an upper limit of 2.98. Furthermore, from the above analysis, there is one study (n = 1) with low effect size criteria, 2 studies (n = 2) with moderate effect size criteria and 11 studies (n = 11) with high effect size criteria.

Furthermore, testing the heterogeneity of each study and selecting the estimation model aims to determine the combined effect size. The results of the heterogeneity test in this meta-analysis and the combined effect results can be seen in Table 4.

Table 4. Combined Heterogeneity and Effect Size Test Results

Model	K	Effect Size	95 % CI	p	df	Heterogeneity		
						Q	p	I2
Random	14	1.30	[0.79; 1.17]	0.00	13	79.14	0.00	87.72
Fixed	14	1.24	[1.45 ;1.70]	0.00	13			

Based on Table 4. Obtained a Q value of 79.14> Chi square (df = 13). This result explains the diverse effect sizes of this study. So, the random effect estimation model is used in determining the combined effect. The results of the random effect model explain the results of the combined effect, namely ($d = 1.30$; $p < 0.00$). This result explains the effect size value with high criteria. So, it can be concluded that the STEM-based mind mapping learning model has a high influence on students' science literacy compared to conventional learning.

The next step is to analyze the moderator variable. This aims to find out what factors can influence the STEM-based mind mapping learning model on students' science literacy. In this meta-analysis, the moderator variables consisted of education level, publication year and sample size. The results of the moderator variable analysis can be seen in Table 5.

Based on Table 5. Shows the analysis of moderator variables at the level of education effect size in the elementary group with high criteria with ($d = 1.10$; $P < 0.01$), Effect size junior high school group very high criteria ($d = 2.62$; $p < 0.00$) and effect size very high criteria high school group ($d = 2.96$; $p < 0.01$). These results explain that the three groups of education levels have a statistically significant effect ($Qb = 16.10$; $p < 0.05$). These results conclude that the application of STEM-based mind mapping learning model has a significant effect on students' science literacy. Furthermore, the STEM-based mind mapping learning model is more effectively applied at the junior and senior high school levels.

Table 5. Effect Size Based on Moderator Variable

Moderator Variable	k	Effect size (d)	p				Heterogeneity
				Q	df	Qb	P
Education Level							
SD	4	1.10	0.01	23.17	1	16.10	0.00
SMP	6	2.62	0.01	26.80			
SMA	4	2.96	0.01	21.65			
Year of Publication							
2018-2020	5	1.20	0.01	17.97	1	18.19	0.00
2021-2023	9	0.89	0.01	21.70			
Sample size							
Under 25	6	1.08	0.01	15.85	1	2.86	1.02
Above 25	8	1.35	0.01	27.91			

Based on the moderator variable of publication year. The effect size of the publication year 2018-2020 is high criteria ($d = 1.20$; $p < 0.01$) and the effect size of publication in 2021-2023 is high criteria ($d = 0.89$; $p < 0.01$). The results concluded that the year of publication made a significant difference ($Qb = 18.19$; $p < 0.05$). These results explain the application of STEM-based mind mapping learning model gives significant influence on students' science literacy based on the year of publication.

Furthermore, the analysis of moderator variables for the sample size group below 30 students gave a high effect size ($d = 1.08$; $p < 0.01$) and the effect size of the sample size group above 30 students was very high ($d = 1.35$; $p < 0.01$). The results explain that the sample size provides an insignificant difference ($Qb = 2.86$; $p> 0.05$). This finding explains that the application of STEM-based mind mapping learning model does not differ based on sample size. Therefore, the application of this model is effective whether the sample size is above 25 or below 25 students.

The last step calculates the publication bias of each study by using Roshentals Fail Safe N (FSN) test. The results of the Fails Safe N (FSN) test can be seen in Table 6.

Table 6. Results of Publication Bias Test with Fail Safe N (FSN)

File Drawer Analysis	k	FSN	Target Significance	Observed Significance
Rosenthal	14	820	0.05	< 0.01

Based on Table 6. Shows the value of Fail Safe N (FSN) 820 so that the value of k is greater than $5k + 10 = (5.14 + 10) = 80$. The results can be concluded that this meta-analysis research is valid and scientific due to the absence of publication bias.

Discussion

The application of the STEM-based mind mapping learning model has a significant effect on students' science literacy in the era of the industrial revolution 4.0. These results can be seen in Table. 4 the effect size value of each study ($d = 1.30$; $p < 0.00$). This result is in line with (Artayasa et al., 2021) the application of the mind mapping model can help students in improving students' science literacy in the era of revolution 4.0. These results are also supported by research (Prastiwi & Haryani, 2018) The mind mapping learning model increases students' motivation and learning process so as to encourage students' literacy in learning. STEM-based mind mapping learning helps students learn critically, creatively and innovatively (Ristanto et al., 2018; Yore, 2010). Furthermore, the STEM-based mind mapping learning model makes it easier for students to understand the content and materials delivered by the teacher (Polat et al., 2017; Liu et al., 2010).

El Islami et al. (2020) STEM-based mind mapping learning model develops students' potential in increasing students' knowledge in learning. Knowledge is all information obtained by students through various learning sources (Ferry et al., 2019; Rahman et al., 2023; Zulkifli et al., 2022). In addition, research results Lestari et al. (2019) Mind mapping learning helps students more easily develop knowledge that can encourage students' science literacy. Science literacy influences students in facing the industrial revolution 4.0 (Bonney et al., 2009; Winarni, 2020; Jufrida et al., 2019). Furthermore, science literacy helps students solve science problems that occur in life (Simamora et al., 2020; Supriyadi et al., 2023; Dios et al., 2020). Science literacy skills help students more easily learn how to analyze problems that occur in life (Anderson et al., 2020).

Furthermore, STEM-based mind mapping learning effectively improves students' ability to learn compared to conventional learning models. These results are seen in the moderator variables in Table 5 all provide a high effect size of each study. Research results (Wiraputra et al., 2023) mind mapping learning is effective in improving students' science literacy in learning. In addition, the research (Hanim et al., 2020) STEM-based learning models encourage students' mastery of concepts and science literacy in learning. Students who have science literacy find it easier to think critically and creatively in learning (Azizah & Budiyanto, 2020; Ayd, 2020).

Conclusion

From this study it can be concluded that the combined effect size value of ($d = 1.30$; $p < 0.05$) high criteria. This finding explains that the STEM-based mind mapping model is more effective in improving science literacy skills in the era of revolution 4.0 than the conventional learning model. The STEM-based mind mapping learning model provides a new breakthrough in the world of educational technology. The STEM-based mind mapping learning model encourages students to foster a scientific attitude that can solve problems in life. STEM-based mind mapping learning helps teachers and students more easily understand learning technology.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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