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The effectiveness of learning to improve students' higher-order thinking skills

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Abstract

Higher-order thinking skills (HOT) are expected to be skills needed now and in the future. Many learning strategies are applied to increase HOT. However, how effective is this in improving students' HOT abilities? This study will examine how effective learning is to improve HOT thinking skills. We use meta-analysis research techniques to analyze the research quantitatively. We have selected 21 articles from 60 Google Scholars that use models, media, and science learning assessments to improve HOT. Heterogeneity analysis (trim-fill, funnel plot approach, and Z value calculation) was used to prove the absence of publication bias. Forest plot analysis showed an average increase in learning effectiveness of 0.32 on the moderate effect. It shows that the effectiveness of learning is supported by strategies for using media, methods, and strategies for assessment. These factors are proven to increase the effectiveness of students' HOT abilities.

Keywords: HOTs, learning, meta-analysis;

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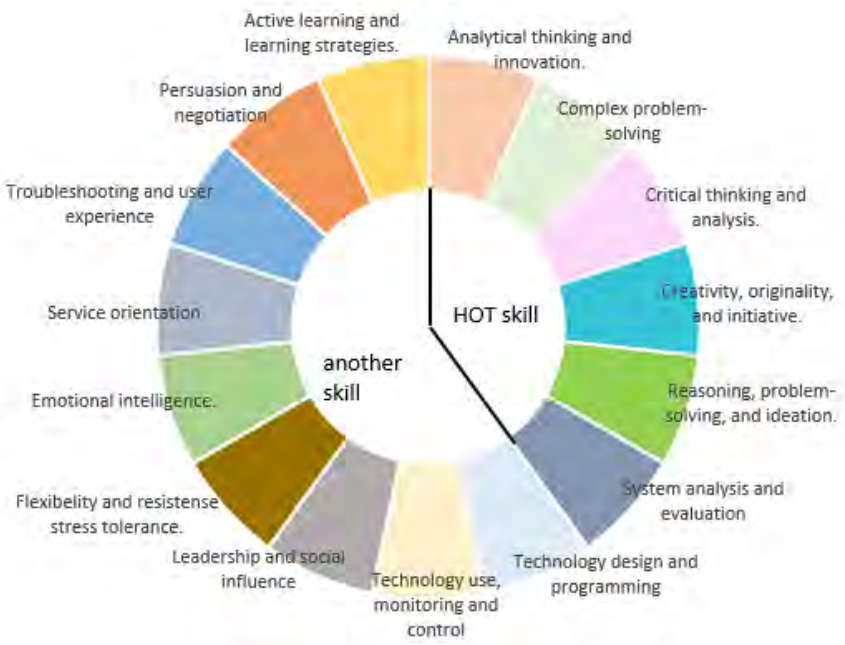
1. Introduction

Educational reform in the 21st century is moving very fast (Rienties et al., 2022). The ability of reliable human resources is needed in this era (Ananiadou & Claro, 2009). HOTs have become the focus of 21st-century education with the hope to foster higher scientific thinking, critical thinking, and reasoning among humans. Data from the World Economic Forum (WEF) 2020 recorded 15 skills needed by today's working world (World Economic Forum, 2020). Figure 1 is the 15 highest skills needed by the world until 2025 according to WEF 2020. WEF data records show that 7 out of 15 abilities characterize higher-order thinking skills (HOTs). By 2025 HOTs are predicted to become the required skills. The world economy requires people with analytical, creative, problem-solving skills, and critical thinking about problems.

Figure 1. Skill identified as high demand by 2025



The international student assessment program organized by the Organization for Economic Cooperation and Development (OECD), 2018 conducted an assessment for mathematics, science, and literacy lessons which is often referred to as the Program for International Student Assessment (PISA) (OECD, 2019). The results of the PISSA assessment followed by 82 countries (figure 2) showed that 28% of countries scored above 500, another 28% scored 450 - 500, and another 44% scored below 450. The data proves that the ability of HOTs is not only the problem of education in only one or two countries but also in many countries. Learning using various strategies, such as models, media, and assessments, has been carried out to improve HOT abilities. However, is learning strategies increase students' HOT abilities? It needs to be studied more deeply. The effective and efficient learning outcomes must attract students' interest. The higher the interest and enthusiasm of students in learning, the higher the effectiveness.

Learning is an activity carried out by students and teachers (Hamdan et al., 2019; Stošić, 2015). Learning will consist of several interacting components. The components of students, teachers, teaching materials, media (Puspitarini & Hanif, 2019; Zhdanko, 2019) and the learning environment

must interact. Learning can be successful and effective if designed and developed based on student characteristics.

Problems, questions, or stimuli spontaneously cause HOT skills to be formed. Teachers and educational institutions have made various efforts to improve the ability of HOTs. The effort has been started from education, ranging from low education to higher education. However, are these efforts effective in improving students' HOTS abilities? This study will examine learning effectiveness to improve students' HOT abilities with various media, methods, and assessment strategies.

Figure 2. Average score PISA 2018 (OECD, 2019)

2. Material and Metods

2.1. Reseach design

This meta-analysis is a quantitative study (M. Borenstien, L. Hedges, J.P. Higgins, 2021). Meta-analysis research using correlation meta-analysis. Meta-analysis is used to find correlations between independent and dependent variables (J.E. Hunter, 2004; Camnalbur et al., 2013). The research observed in this study was learning HOT with various methods as the independent variable and increasing HOT skills as the dependent variable. This research was conducted by collecting articles related to HOTS with the learning method followed by statistical analysis. Article collection begins by analyzing the effectiveness of learning in various ways, such as learning methods or strategies or learning media. It is used to comprehensively evaluate the effectiveness of learning HOTs by increasing the ability of HOTs. The analysis is done by collecting quantitative data, such as the number

of samples (N), correlation coefficient (r), and effect size (F) values in the form of numerical values. Statistics will evaluate numerical information.

According to the statistical sense, measuring the strength of the relationship between variables is determined by the size of the effect (Camnalbur et al., 2013; Harpe et al., 2015; Hussein & Zayed, 2021; M. Borenstien, L. Hedges, J.P. Higgins, 2021; Nugraha & Suparman, 2021). In this study, the effect size refers to the relationship between the effectiveness of HOTs learning and the improvement of students' HOTs abilities. Effect sizes are related to observations from different studies, which are then measured.

2.2. Data collection

Data collection with several stages, namely: (a). Search step. The search step is a search for research published on Google Scholar containing keywords about HOT learning and ability improvement, HOT learning effects, learning media, and learning strategies. (b). Screening stage. The screening stage with selecting articles that have similarities with this study, with quantitative data. (c) Selection stage. The selection stage tries to select articles that are relevant to quantitative data in the form of the number of samples, correlation values, effect size values, if any, or F and t.

2.3. Coding.

The search results found 21 articles that matched 60 articles that had appropriate quantitative data and variables. Articles are taken from various journal sources on Google Scholar. The research subjects were confirmed to come from countries that took the 2018 PISA test. The twenty-one articles were coded, and the quantitative description sought, such as the number of samples N, r-value, or F.

2.4. Data analysis

Before data analysis, the data is completed by finding the value of r or F. The calculation step for r is carried out if the value of r is not known by finding the value of t. The $F = t^2$ or $t = \sqrt{F}$ and r is searched for by equation 1. (M. Borenstien, L. Hedges, J.P. Higgins, 2021).

$$r = \frac{t}{\sqrt{t^2 + N - 2}} \qquad (1)$$

The next stage is data analysis by: (1) heterogeneity test. This test aims to determine the similarity of the research used (2) publication bias test. The aim is to find out biased publications (3) Test effect size to calculate the effect size, (4) describe in forest plots and funnel plots, (5) test hypotheses. All analyzes are using the JASP 0.14.10 program. Effect sizes categorized according to Table 1 (L. Cohen, L. Manion, 2018; Rahmat Hidayat & Alfan, 2020).

Table 1. Classification of effect size

Value	Category
0.00 – 0.20	Weak effect
0,21 - 0.50	Modest effect
0.51 – 1.00	Moderate effect

> 1.00	Strong effect

3. Result

The article search results were seen in the article data described in Table 2. Each article is given a name index to facilitate naming. The data in table 2 consists of the number of samples (N), r, t, and F. The results of the qualitative analysis to test the heterogeneity of the sample can be observed in Table 3 and Table 4.

Table 2. Article selection results

Subject	*Learning strategies*	*N*	*r*	*t*	*F*
M. Susie (Whittington, 1995)	assesment	217	0.360*	-	-
Jennifer L(L. Jennifer, B. Bretel, 2013)	assesment	112	-	1.809	-
Prayoonsri (Harpe et al., 2015)	assesment	71	0.762*	-	-
Saptono (Saptono, 2016)	assesment	61	0.031	1.977	-
Dr. Divya (Sukla & Dungsungneon, 2016)	assesment	785	0.179*	-	-
Sara B (Brierton et al., 2016)	method	9	0.002	5.810	-
Benidiktus (Tanujaya et al., 2017)	assesment	41	0.814*	8.754	.330
Adam Malik(Adam Malik et al., 2017)	media	40	0.948*	6.496	7642.198
A Malik (A. Malik et al., 2018)	media	60	0.060	-	-
Metri D(Insani et al., 2019)	method	98	-0.049	-7.260	52.708
Kartika C (Suryandari & Sajidan, 2019)	method	121	0.120	3.847	14.800
Beatrix E (Dasilva et al., 2019)	media	901	0.001	0.566	0.320
Nuraffefa H (Hamdan et al., 2019)	method	78	-	-	114.999
Bayu P(Pranata et al., 2020)	method	67	-	-	28.286
Hye Jeong Kim (Kim et al., 2020)	media	456	0.358*	-	-
Dwi Isnaini Amin (Amin & Ikhsan, 2021)	method	81	-	-	11.642
Sari S (Sari Saraswati, 2021)	assesment	61	0.010	-	-
M Aunur (Rofiq & Nurwulandari, 2021)	method	17	0.241	-7.800	60.840
Parlan (Parlan & Rahayu, 2021)	method	62	0.877*	-	-
I Yusuf (Yusuf & Widyaningsih, 2019)	media	53	-0.336*	-4.430	19.625
Kaili Lu; Harri (Lu et al., 2021)	method	217	-	-	9.276

Note: = not significant, *****= significant (alpha 5%)

In Table 3, the Q value on the Omnibus test was 7.260 with a p-value of 0.007 where p <0.05, indicating that the sample satisfies the assumption of study heterogeneity. Based on the estimated residual heterogeneity value in table 4, which shows the value of τ^2 of 0.270 or 0.520, all were > 0. The value of I^2 (%) in Table 5 is 97.624%, close to 100%. This assumption also shows that the sample used fulfilled the heterogeneity assumption. After passing the sample heterogeneity test, the next step used the summary of estimated effect size and publication bias by applying the random effects approach.

Table 3. Fixed and Random Effects

	Q	df	p

Omnibus test of Model	7.260	1	0.007
Coefficients			
Test of Residual Heterogeneity	350.376	20	< .001

Note. *p* -values are approximate.

Table 4. Residual Heterogeneity Estimates

	Estimate
τ^2	0.270
τ	0.520
I^2 (%)	97.624

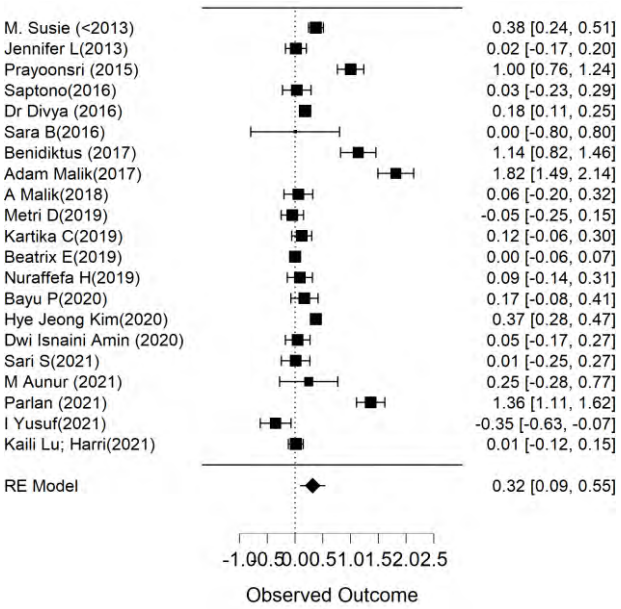


Figure 3. Forest plot

Table 5. Rank correlation test for Funnel plot asymmetry

	Kendall's **τ**	**p**
Rank test	0.201	0.204

Table 6. Regression test for Funnel plot asymmetry ("Egger's test")

	z	p
sei	0.499	0.618

Table 6 and table 5 are the results of the publication bias test. Both the Egger test and the Rank correlation test for the asymmetry of the Funnel plot test whether these studies can be combined or not. The Kendal value was 0.201 in table 5 with a p-value of 0.204, greater than 0.05. The Z value in table 7 was 0.499 with a p-value of 0.618, greater than 0.05. Therefore, it concluded that there was no

publication bias in the sample. These results were supported by the diagnostic trim-fill analysis of the funnel plot.

The funnel plot from the diagnostic results of Figure 4 and Forest plot of Figure 3, with the trim-fill analysis approach, did not add blank dots (hollow dots). Blank marks are a hallmark of publication bias or missing research in Trim Fill analysis. So it can be concluded that all the total marks in Figure 4 indicate that there was no publication bias in this study, or it can say that there was a significant relationship between learning strategies and increasing ability in HOTs.

This conclusion is the strength of analyzing the P-value for hypothesis testing. Hypothesis Ho stated that there was no positive and significant relationship between learning effectiveness and increasing the ability of HOTs. Hypothesis Ha stated a positive and significant relationship between learning effectiveness and increasing HOTs ability. Based on the average value of effect size M of 0.32 and SE of 0.118, the Z=M/SE value of 2.711 was obtained. So, the value of p = 1 – NORMSDIST (2.711). Therefore, p-value = 0.0033 then p-value <0.05 had a 95% confidence interval. Thus, the Ho hypothesis was rejected, which means a positive and significant relationship between learning effectiveness and increasing HOT abilities

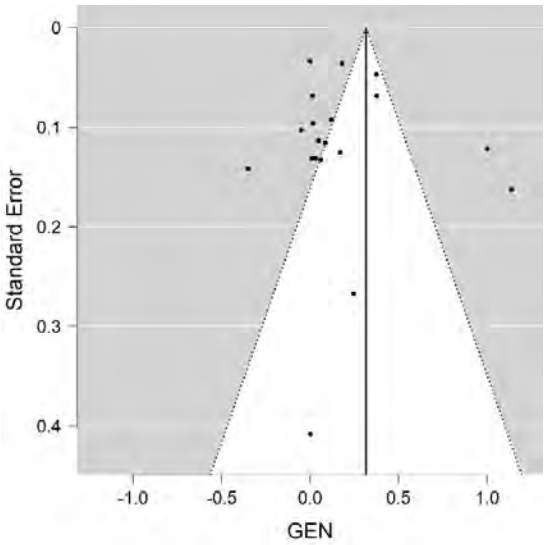


Figure 4. Funnel Plot

4. Discussion

The results of the summary size estimation of the effect size on the forest plot in Figure 3 and the categorization of the effect size according to Table 2 (L. Cohen, L. Manion, 2018), show the effectiveness of learning in increasing the ability of HOTs in each research article can be categorized as in Table 8.

Table 8. Categories of Learning Effectiveness

Subject	***Categories***
M. Susie (Whittington, 1995)	Increase modest effect
Jennifer L Ramos (L. Jennifer, B. Bretel, 2013)	Increase weak effect
B. Prayoonsri (Harpe et al., 2015)	Increase moderate effect

Saptono(Saptono, 2016)	Increase weak effect
Dr. Divya (Sukla & Dungsungneon, 2016)	Increase weak effect
Sara B(Brierton et al., 2016)	Increase weak effect
Benidiktus (Tanujaya et al., 2017)	Increase strong effect
Adam Malik(Adam Malik et al., 2017)	Increase strong effect
A Malik(A. Malik et al., 2018)	Increase weak effect
Metri D(Insani et al., 2019)	Decreases effect
Kartika C(Suryandari & Sajidan, 2019)	Increase weak effect
Beatrix E(Dasilva et al., 2019)	Increase weak effect
Nuraffefa H(Hamdan et al., 2019)	Increase effect weak effect
Bayu P(Pranata et al., 2020)	Increase weak effect
Hye Jeong Kim(Kim et al., 2020)	Increase modest effect
Dwi Isnaini Amin (Amin & Ikhsan, 2021)	Increase weak effect
Sari S(Sari Saraswati, 2021)	Increase weak effect
M Aunur (Rofiq & Nurwulandari, 2021)	Increase modest effect
Parlan(Parlan & Rahayu, 2021)	Increase strong effect
I Yusuf(Yusuf & Widyaningsih, 2019)	Decreases effect
Kaili Lu (Lu et al., 2021)	Increase weak effect

Figure 5 shows that effective HOT capability improvement is carried out by: (1) developing a strategy measurement, (2) developing a strategy for using media, and (3) developing a learning method strategy. Improving students' HOT abilities with weak effects is dominated by using learning methods. Learning using media is dominant, improving students' HOT abilities with simple effects. HOT abilities with the medium effect are dominated by assessment strategy. Meanwhile, the increase in students' HOT abilities with a strong effect is dominated by media learning. It shows that using models, media, or assessment strategies positively influences students' HOT abilities. Learning methods that focus on developing students' thinking skills (Ganyaupfu, 2013) by exploring facts or theories or children's experiences as material for solving the problems posed strongly encourage students to learn more deeply and settle down (Magulod, 2019). Learning media is a strategic instrument in determining the teaching and learning process (Puspitarini & Hanif, 2019). Learning media can provide dynamics for students because learning media is a tool used to make communication and interaction between teachers and students more effective. Higher-order thinking skills can be developed through learning (Hidayati & Irmawati, 2020) and assessment (Widana, 2017), and practice. Various test assessment techniques and strategies can not only be used as a tool to determine a student's ability profile (Ryerson University, 2016) but can also be used as a means to train students' thinking skills.

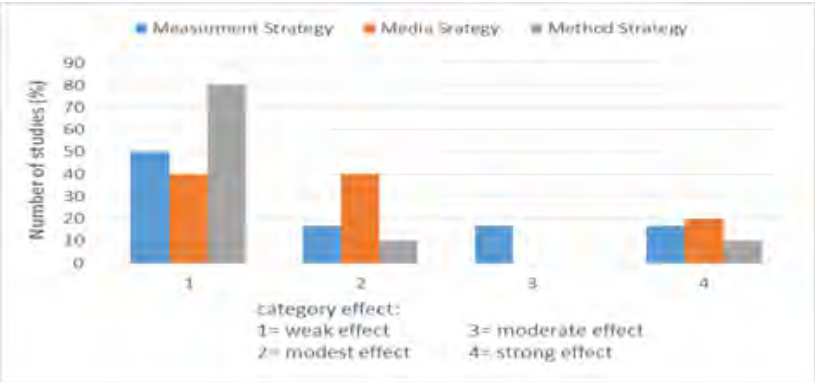


Figure 5. The effectiveness of improving HOT in measurement, media, and method strategy

Learning is a conscious effort process by individuals to produce changes from not knowing to know, from not having the attitude to being right, from being unskilled to being skilled at doing something. Learning will involve students actively to be an experience that is beneficial for them (Deslauriers et al., 2019). Because of that, there will be a link between the media, methods, and assessment techniques. Learning material is a message that students will convey. HOT-based learning media is a place or package used to convey the message to students. The learning process in the form of HOT learning strategies and HOT assessment strategies is the goal used by the teacher to convey the message. Therefore, learning effectiveness to improve students' HOT abilities can be packaged in developing media, developing methods, or developing assessment strategies. These three things cannot be separated in improving students' HOT abilities.

5. Conclusions

Meta-analysis techniques can prove publication bias and the heterogeneity of the observed article sample. The Q value proves the heterogeneity of the articles in the Omnibus test of 0.007 <0.05. This conclusion is heterogeneous, reinforced by the estimated residual value, which shows a value of ² of 0.270, of 0.520, all of which are > 0. The value of I^2 (%) is 97.624% or close to 100%. Publication bias test with Egger test and Rank correlation test for funnel plot asymmetry resulted in Kendal value = 0.201 and p-value = 0.204, which is more than 0.05. The Z value in table 6 is 0.499 with a p-value of 0.618, more than 0.05. The funnel plot of the diagnostic results with the trim-fill analysis approach did not have additional (incomplete) blanks. It all proves that there is no publication bias in the sample.

The effectiveness of learning improves HOT thinking ability. The Forest plots obtained an average increase in the effectiveness of 0.32 with an interval of 0.09 to 0.55. The effectiveness of learning is supported by strategies for using media in learning, methods in learning, and assessment strategies for students. These factors are proven to increase the effectiveness of students' HOT abilities. HOTs can be grown through instructional media strategies, learning methods and assessments. Learning media is a place used to convey messages. Methods and assessments are the goals to be achieved by the teacher in conveying the message. Therefore, learning to improve students' HOT abilities is effective if packaged by developing media, developing methods, and developing assessment strategies. These three things cannot be separated in improving students' HOT abilities.

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