Al-Jabar: Jurnal Pendidikan Matematika
Volume 14, Number 1, 2023, Pages 37 – 53
http://ejournal.radenintan.ac.id/index.php/al-jabar/index

Students' heterogeneous mathematical critical thinking skills in problem-based learning: A meta-analysis investigating the involvement of school geographical location

Suparman[1]*, Dadang Juandi[1], Bambang Avip Priatna Martadiputra[1]
[1] Universitas Pendidikan Indonesia, Jawa Barat, Indonesia
✉ arman95@upi.edu*

Article Information
Submitted March 15, 2023
Revised May 15, 2023
Accepted May 22, 2023

Keywords
Misconceptions; Scientific attitudes; Geometry; Information technology transformation

Abstract

A discrepancy exists in students' mathematical critical thinking skills (MCTS) in mathematics classrooms implementing problem-based learning (PBL). The factor of school geographical location is predicted to affect the skill distinction of the students. This study aims to investigate and examine the school's geographical location assumed as a moderating factor of students' heterogeneous MCTS in PBL. Meta-analysis of 58 relevant documents containing 3,946 students and generating 59 effect sizes in the Hedges g unit was performed to conduct this study. Searching and selecting literature found 58 documents published from 2011 to 2021, consisting of 40 journal articles and 18 conference papers. Some tests, such as Q Cochrane and Z, were applied to analyze the data. The results showed that the school's geographical location was not a significant moderating factor that affected students' heterogeneous MCTS in PBL. In addition, PBL intervention significantly positively affected metropolitan, urban, and rural students' MCTS. Still, PBL intervention was more effective in the metropolitan area in enhancing students' MCTS than in urban or rural areas. This study suggests Indonesian government conduct the equable distribution of competent teachers and complete the facility and infrastructure of schools in each geographical location.

INTRODUCTION

The fast expansion of technological development in the 21st-century supplies unlimited information for every people (Bellamy, 2007). The huge provided information positively affected students, like beneficial information to develop their talent and potency. However, the abundant information also hurts them when sharing hoax information (Epafras et al., 2019). Moreover, Bellamy (2007) stated that the deployment of hoax information is affected by the low level of students' critical thinking, so they need help analyzing, clarifying, and filtering the validity of each piece of information they obtain. Thus, the spread of information is received by people mostly without the precise and accurate process of analysis, clarification, and filtering. This indicates that critical thinking is an important skill to be enhanced in formal education, especially in mathematics learning.

Some literature presented that critical thinking is a complex skill with a high thinking level process involving the existing information evaluation (Liu et al., 2015; Wechsler et al., 2018). Thinking critically requires students to organize, interpret, analyze, evaluate, infer, and explain the information in mathematics learning (Alghafri & Ismail, 2014; Sanders, 2016). Moreover, Sanders (2016) revealed critical mathematical thinking could be claimed as an essential skill that must be enhanced in students, especially in learning mathematics. In enhancing students' critical thinking, some literature recommends PBL as an alternative solution (Hmelo-Silver, 2004; Torp & Sage, 2002; Yew & Goh, 2016). The design of PBL can

How to cite: Suparman, Juandi, D., and Martadiputra, B. A. P (2023). Students' heterogeneous mathematical critical thinking skills in problem-based learning: A meta-analysis investigating the involvement of school geographical location. *Al-Jabar: Pendidikan Matematika*, *14*(1), 37-53.
E-ISSN: 2540-7562
Published by: Mathematics Education Department, UIN Raden Intan Lampung

intensify and develop students to think critically. It can generate students as a critical individuals equipped with the capacity to analyze, verify, and justify the true and valid news they obtain, and they can adjust in numerous situations and conditions (Nargundkar et al., 2014; Neber & Neuhaus, 2013; Sulaiman et al., 2014). This suggests that PBL can be an alternative way to improve students thinking critically in mathematics.

To date, many meta-analysis types of research have studied the influence of PBL on the MCTS of students, in which these studies found a discrepancy in the MCTS of the PBL process. Some studies reported that the discrepancy of the MCTS of students in the process of PBL was moderated by several factors, including intervention duration (Nugraha & Suparman, 2021b; Yohannes et al., 2021), mathematical content (Juandi et al., 2022; Nugraha & Suparman, 2021b), research area (Nugraha & Suparman, 2021a), research year (Juandi & Tamur, 2021; Suparman, Juandi, & Tamura, 2021a; Yohannes et al., 2020), and sampling technique (Suparman et al., 2021). These reports indicate that those factors indirectly cause the different MCTS of students in the PBL process. It means that the moderating factors are indirectly involved in the PBL intervention process to help students think critically in mathematics. Hence, the intervention of PBL has a weak, modest, moderate, or strong effect on students' MCTS.

In detail, Lipsey and Wilson (2001) categorized the moderating factor into three groups: substantial, irrelevant, and method. Many meta-analysis studies have investigated and examined the substantial and extrinsic factors predicted to have a role in the heterogeneity of students' MCTS in the process of PBL. Some substantial factors such as group size of the intervention, educational level, intervention duration, sampling technique, research area, and research year have been conducted extensively (Juandi & Tamur, 2021; Nugraha & Suparman, 2021a, 2021b; Suparman et al., 2021; Suparman, Juandi, & Martadiputra, 2021; Suparman, Juandi, & Tamura, 2021a; Suparman Suparman et al., 2021; Yohannes et al., 2020, 2021). In addition, some extrinsic factors such as publication year and indexer have been sufficiently carried out (Suparman et al., 2021; Suparman, Juandi, & Tamura, 2021a). However, another substantial factor, like the school's geographical location, has yet to be explored and examined. As a sequence, this study of meta-analysis focuses on the factor of school geographical location predicted to have a potency toward the discrepancy of students' MCTS in the PBL process.

School geographical location is one of the substantial factors predicted to involve students' heterogeneous MCTS in the PBL process. Some empirical studies revealed that school geographical location and academic achievement have a positive relationship (Falch et al., 2013; Musa, 2013; Suadi et al., 2021). It indicates that there is an opportunity for the school's geographical location factor to be involved in the PBL process so that it causes students' MCTS to be heterogeneous. Furthermore, Muzayanah et al. (2020) stated that the geographical location of school institutions is classified into three groups that are metropolitan, urban, and rural. Many metropolitan schools have more qualified institutions than urban or rural schools in which they have a lot of competent teachers supported by sophisticated classroom facilitation (Tayyaba, 2012). In addition, metropolitan and urban students have extensive access to enhance their academic achievement, especially mathematics achievement, in the various courses provided by non-formal educational institutions (Pangeni, 2014). However, A few empirical studies showed no difference in academic achievement between urban and rural students (Horswill, 2011; Pangeni, 2014; Suparman et al., 2021). This indicates that there needs to be consistent information related to students' academic achievement based on their school's geographical location, mainly regarding students' mathematics achievement. Consequently, an important study has to be conducted regarding the impact of school geographical location factors in implementing the PBL for enhancing students' MCTS. Moreover, the phenomenon related to the heterogeneity of students' MCTS that is possibly affected by the factor of school geographical location can be a main problem whereby there is a significant gap of MCTS between metropolitan, urban, and rural students that has to be found its solution by the Indonesian government as soon as possible.

This current study of meta-analysis proposes to explore and examine the impact of school geographical location factors on students' heterogeneous MCTS in the PBL process. The following research questions are directed to achieve the purpose of this recent study:

1. Does school geographical location moderate students' heterogeneous MCTS in the PBL process? Are there any different MCTS among students staying in metropolitan, urban, and rural students?
2. What is the effect size of PBL interventions toward metropolitan, urban, and rural MCTS of students? Does PBL implementation enhance metropolitan, urban, and rural students' MCTS?

METHOD

To achieve the aim of this study, a meta-analysis was applied in conducting this study. Some pieces of literature argue that meta-analysis is a sequence of quantitative methods to synthesize some relevant studies related to a certain topic to approximate, investigate, and examine the strength among variables by using the effect size unit (Borenstein et al., 2009; Cleophas & Zwinderman, 2017; Cumming, 2012; Mike & Cheung, 2015). A random effect model was chosen as an approximation model to estimate the effect size because the collection of documents involved in this study had heterogeneous characteristics, which means that some characteristics, such as assessment instruments, populations, educational level, and prior mathematics knowledge, are heterogeneous. Thus the true effect can be varied from one study to another (Borenstein et al., 2009; Lipsey & Wilson, 2001). To conduct a meta-analysis study, Hunter & Schmidt (2004) proposed seven steps (See in Figure 1).

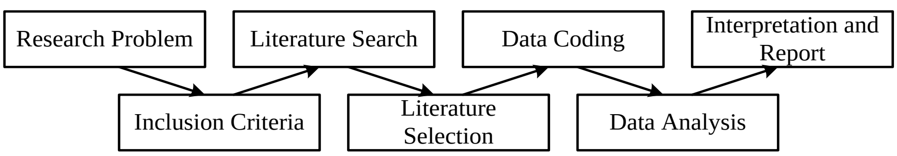

Figure 1. The Procedure of Meta-Analysis

Inclusion Criteria

Some inclusion criteria were established in this study to restrict the extensive research question. Those inclusion criteria were such as: (1) the document prepared adequate statistics data for computing the effect size; (2) the document intervention was problem-based learning; (3) the document was published from 2011 to 2021, and all documents were also indexed by Web of Science, Scopus, and Google Scholar; (4) the conventional learning (CL) was used as the comparator in the document (5) all documents were written well both English and Indonesia; (6) the participant in the document was students in Indonesia from primary school until college/university; (7) the outcome in the document was critical thinking skills in mathematics;

and (8) the design of the study involved was the quasi-experiment study. Consequently, the document which was inappropriate to the study's criteria was removed.

The Search and Selection of Literature

A few databases, including Google Scholar, Scopus, and Web of Science, were utilized to search the literature. In addition, some combinational keywords, namely "problem-based learning" as well as "mathematical critical thinking skills" or else such as "mathematical critical thinking ability," are used to ease the searching process of finding the literature. The results of the literature search found 73 documents indexed by Scopus, followed by 51 documents indexed by Web of Science and 157 documents indexed by Google Scholar, which these documents were selected based on the inclusion criteria. Furthermore, some references stated that there are four steps to selecting the literature systematically (Fuad et al., 2022; Liberati et al., 2009; Moher et al., 2009). In detail, the process of selecting the literature is presented in Figure 2. Figure 2 shows that 58 remaining documents were established to be the data in this study because those documents were eligible and suitable to the inclusion criteria. Subsequently, each document's data will be extracted to head the coding sheet.

Data Coding

The information consisted of numerical data, including mean, p-value, sample size, t-value, and standard deviation. Categorically data such as author(s), school geographical location, publication year, document type, and database were extracted from the coding sheet. The categorical data from the coding sheet is shown in Table 1.

Table 1. Categorical Data

Categories	Groups	Frequency	Percentage
School Geographical Location	Metropolitan Area	12	20.68
	Urban Area	22	37.94
	Rural Area	24	41.38
Document Type	Journal Article	40	68.97
	Conference Paper	18	31.03
Database	Scopus	28	48.28
	Web of Science	10	17.24
	Google Scholar	20	34.48
Publication Year	2021	4	6.90
	2020	14	24.14
	2019	10	17.24
	2018	8	13.79
	2017	5	8.62
	2016	3	5.17
	2015	5	8.62
	2014	4	6.90
	2013	3	5.17
	2012	1	1.72
	2011	1	1.72

To ensure that the data extracted from each document to the coding sheet was correct (Fuadi et al., 2021; Jaya & Suparman, 2021; Suparman, Juandi, & Tamura, 2021b, 2021c), two lecturers who had expertise in statistics were involved in this study to verify the data repeatedly. Later, the test of Cohen's Kappa was performed to examine whether the coding process conducted by these coders was consistent (Cooper et al., 2013). McHugh (2012) proposed that Cohen's Kappa was formulated as the following equation:

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

The results of Cohen's Kappa toward some items calculated using the SPSS software are shown in Table 2.

Table 2. The Results of the Cohen's Kappa Test

Items	The value of Kappa	The level of agreement	Sig.
Authors	0.923	Strong	0.000
Mean of PBL group	0.802	Strong	0.030
The standard deviation of the PBL group	0.965	Strong	0.000
A sample size of the PBL group	0.813	Strong	0.003
Mean of CL group	0.843	Strong	0.006
The standard deviation of the CL group	0.918	Strong	0.000
A sample size of the CL group	0.847	Strong	0.000
t-value	0.964	Strong	0.000
p-value	0.852	Strong	0.003
School geographical location	0.843	Strong	0.019
Document Type	0.813	Strong	0.003
Database	0.903	Strong	0.005
Publication year	0.802	Strong	0.030

Table 2 shows that each item's significant values were less than 0.05. It interprets that's two coders significantly approve the data extracted from each document to the coding sheet. The extracted data is valid and credible (McHugh, 2012).

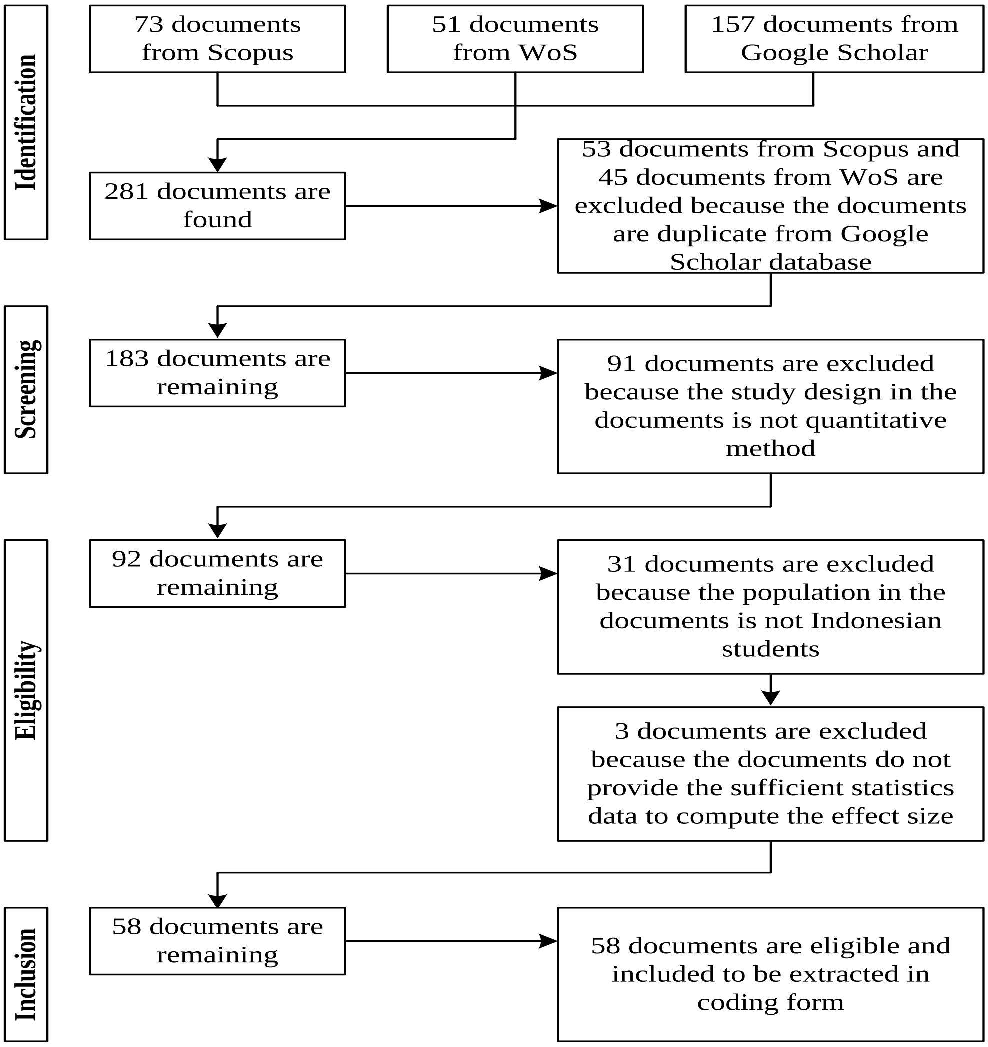

Figure 2. The Process of Document Selection

Data Analysis

In computing the effect size, the equation of Hedges was applied because the equation accommodated the document, which had any sample size (Lipsey & Wilson, 2001). Borenstein et al. (2009) stated the formula of Hedges' equation as follows:

$$g = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}} \times \left(1 - \frac{3}{4df - 1}\right)$$

The effect size in the g unit was classified as weak (g = 0.00 – 0.20), modest (g = 0.21 – 0.50), moderate (g = 0.51 – 1.00), and strong (> 1.00) (Cohen et al., 2018). Additionally, the Z test was performed to examine the significant PBL intervention in enhancing students' MCTS in metropolitan, urban, and rural areas (Borenstein et al., 2009). Moreover, the test of Q Cochrane t was performed to examine the significance of the factor of the school's geographical location in moderating the students' heterogeneous MCTS in the PBL process (Higgins et al., 2003).

Statistically, the published studies tend to have publication bias (Fuadi et al., 2021; Jaya & Suparman, 2021). Therefore, the set of effect size had to be examined for its tendency to publication bias. Some tests, such as the test of trim and fill and the analysis of funnel plot were applied in examining the publication's bias (Rothstein et al., 2005). The plot analysis reveals symmetrical effect size distribution (See Figure 3).

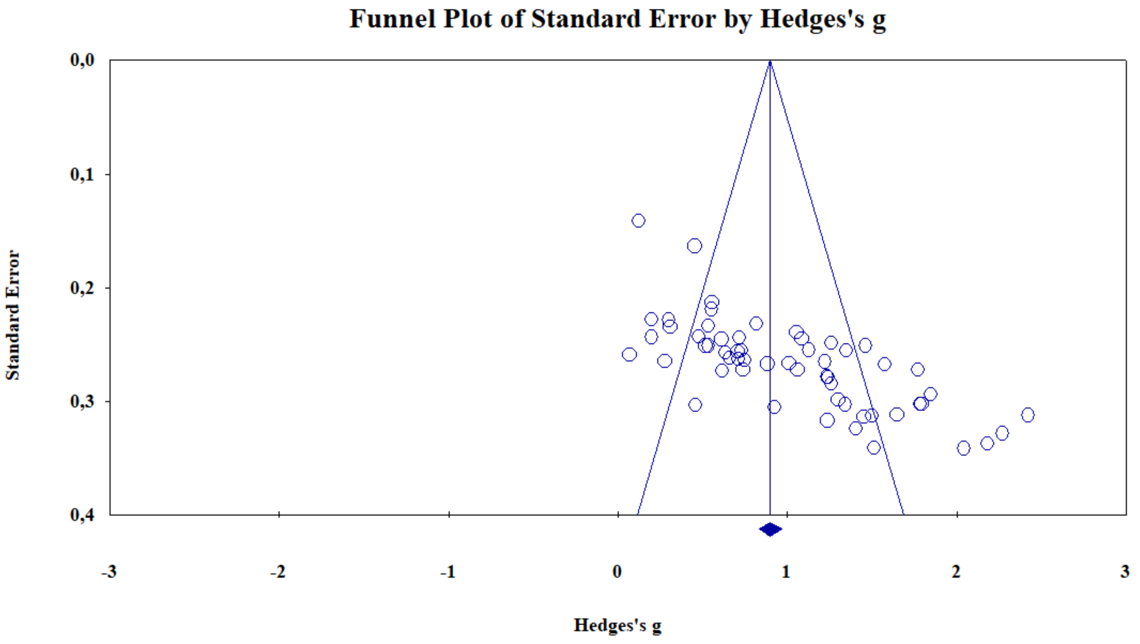

Figure 3. The Distribution of Effect Size in the Funnel Plot

To ensure that the process of the effect size distribution of the data in the plot was symmetrical, another test, namely the test of trim and fill, was conducted (See Table 3).

Table 3. The Results of the Trim and Fill Test

	Documents trimmed	The unit of g	Q-value
Observed values		1.003	262.911
Adjusted values	0	1.003	262.911

Table 3 shows that all of the documents were included in the study. It means the effect size distribution in the plot is symmetrical. Consequently, it interprets the set of effect size from the published studies that did not tend to publication bias (Suparman, Juandi, & Tamura, 2021b, 2021c).

RESULT AND DISCUSSION

The Profile of Effect Size Data

The factor of school geographical location of this study was categorized to be three groups that were metropolitan, urban, and rural. The effect size distribution according to the categorization of Cohen et al. (2018) is presented in Figure 4.

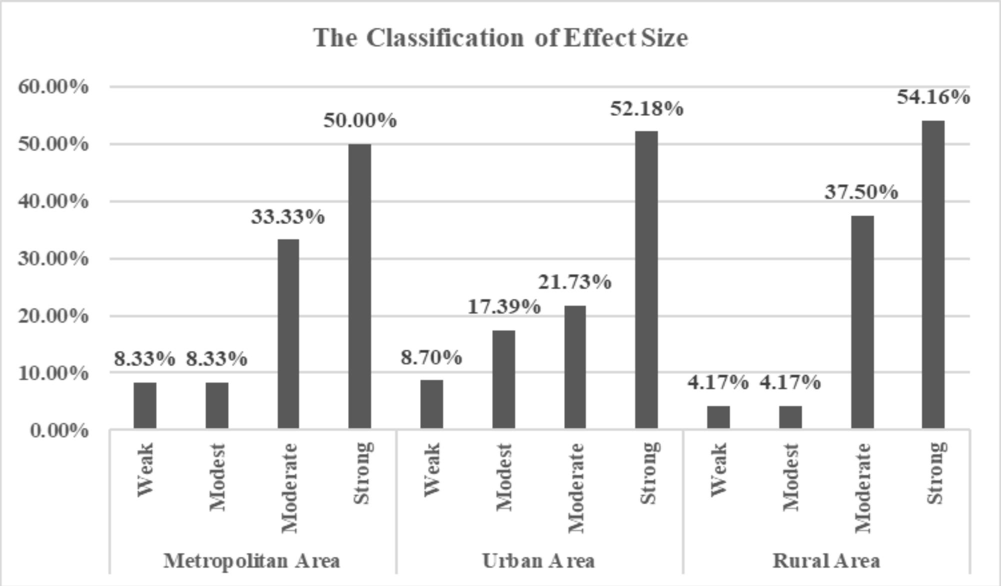

Figure 4. The Distribution of Effect Size

From 58 included documents, there were 59 data of effect size in which twelve effect sizes were distributed to the metropolitan area group, followed by 23 effect sizes to the group of the urban area and 24 effect sizes to the group of rural area. Figure 4 shows that of twelve effect sizes distributed in the group of metropolitan areas, six effect sizes were classified as strong, followed by four moderate effect sizes, one modest effect size, and one weak effect size. Meanwhile, of 23 effect sizes distributed in the group of urban areas, twelve effect sizes were classified as strong, followed by five moderate effect sizes, four modest effect sizes, and two weak effect sizes. On the other hand, of 24 effect sizes distributed in the group rural areas, there were 13 effect sizes classified as strong, followed by nine moderate effect sizes, one belongs to the modest effect size, and another is classified as weak effect size.

Average of Effect Size for Each Group

The overall effect size from each group in the factor of school geographical location and the significant PBL intervention in every group on students to think critically in mathematics are shown in Table 4.

Table 4. Summary of Effect Size and Significance of Each Group

School geographical location	Number documents	Effect size	The smallest effect size	The highest effect size	Z-value	P-value
Metropolitan Area	12	1.073	0.753	1.393	6.572	0.000
Urban Area	22	1.034	0.803	1.264	8.798	0.000
Rural Area	24	0.942	0.716	1.167	8.189	0.000

Table 4 shows that the PBL implementation in both metropolitan and urban schools had a strong positive effect on students' MCTS. Moreover, the process of PBL significantly enhanced metropolitan and urban students' MCTS. Meanwhile, the implementation of PBL in rural schools had a moderately positive effect on students' MCTS, in which rural students' MCTS significantly could be enhanced by the process of PBL. These findings indicate the PBL intervention effectively improves students thinking critically in mathematics who study in metropolitan, urban, or rural schools.

Heterogeneity of Effect Size

In examining the significance of the school's geographical location as a factor in moderating the different MCTS of the students, the Q Cochrane test was performed (Higgins et al., 2003).

Table 5. The Results of Heterogeneity Analysis

The factor of the school's geographical location	Effect size	The Q Cochrane test		
		Q-value	Degree of freedom	P-value
Metropolitan Area	1.073	0.536	2	0.765
Urban Area	1.034			
Rural Area	0.942			

Table 5 reveals the significant value from the Q Cochrane test was higher than 0.05. Thus, the school's geographical location is not a significant factor in moderating students' heterogeneous MCTS. As a sequence, the gap in the MCTS level of students in the implementation of PBL is not affected by the factor of the school's geographical location. In addition, it indicates no difference in MCTS between metropolitan, urban, and rural students even though descriptively, through the process of PBL, metropolitan students' MCTS is slightly higher than urban and rural students' MCTS.

Discussion

More than 50% of studies in each group of school geographical location reported if the intervention of the PBL contributed to a strong effect regarding the MCTS of students. It indicates that metropolitan, urban, or rural students can have high MCTS through implementing PBL. It interprets that MCTS is the same between metropolitan, urban, and rural students who study in the mathematics classroom implementing the intervention of PBL. Even though most of the studies involved the intervention of PBL for their MCTS revealed that the implementation of PBL was effective for enhancing their MCTS, some studies also declared that the intervention of the PBL implementation seems to contribute a lower effect to the students' MCTS in the metropolitan area (Ratnawati et al., 2020; Sari et al., 2020), in the urban area

(Hendriana et al., 2013; Islahuddin et al., 2018; Marinda et al., 2018; Noer & Gunowibowo, 2018; Sumarmo et al., 2012; Sunaryo, 2014), and in the rural area (Arifin et al., 2020; Widada et al., 2019). These reports show the PBL intervention has only partially enhanced students' MCTS in any school geographical location.

Furthermore, the intervention of PBL significantly enhanced students' MCTS in each group of school geographical location. It interprets the PBL intervention as effective for enhancing metropolitan, urban, and rural students' MCTS. In a meta-analysis study conducted in Indonesia, Suparman, Juandi, & Tamur (2021a) revealed that the intervention of PBL also significantly enhances students' MCTS in the western region of Indonesia consisting of Sumatera, Java, and Kalimantan, and the eastern region of Indonesia consisting of Sulawesi, Bali, Maluku, and Nusa Tenggara. This report indicates the intervention of PBL is effective in enhancing the MCTS of students in most of Indonesia. In addition, Nugraha & Suparman (2021a), in a meta-analysis study evaluating Indonesian primary students' MCTS, also reported that the PBL intervention is significantly effective in improving students to thinking critically in mathematics classrooms in most of Indonesia region encompassing Kalimantan Island, Sumatera Island, Sulawesi Island, Bali & South-East Nusa Island, Java Island, Papua Island, and Maluku Island. This evidence strengthens that the PBL implementation can be claimed as the alternative learning model in organizing mathematics learning and effectively enhances students' MCTS in most areas of Indonesia, covering the metropolitan, urban, and rural areas.

The intervention of PBL shows its effectiveness in enhancing students thinking critically in mathematics because it is designed to upgrade the learning quality by collaborating with students and giving them a chance to increase their critical thinking skills (Yew & Goh, 2016). In addition, some kinds of literature state that PBL can be defined as cooperative learning (Hung, 2015; Newman, 2005; Savery, 2006). Moreover, Fuadi et al. (2021) argued that cooperative learning, such as PBL, positively affects students' MCTS. It interprets that PBL is a cooperative learning effective for students in enhancing their MCTS. Furthermore, Torp & Sage (2002) revealed that PBL supported enhancing higher-ordered thinking, such as creative and critical thinking skills. Moreover, Suparman, Juandi & Tamur (2021c) revealed that the PBL intervention significantly positively affected the students' higher-order thinking skills in mathematics. Specifically, the study stated that the intervention of PBL significantly contributed to a strong positive effect on students' MCTS ($g = 1.087$). This interprets that PBL is effective not only for students' MCTS but also for the higher-order thinking skills in mathematics.

Some theoretical research also revealed that PBL is the learning that enhances critical thinking (Du et al., 2013; Nargundkar et al., 2014; Oja, 2011). The intensified enhancement of students to think critically passes the problem stimulations given to them during the learning process (Hmelo-Silver, 2004; Savery, 2006), in which the given problems obligate them to think creatively and critically for solving those problems. As a consequence, students can find the concept and principle of mathematics learning through the process of problem-solving. It means that indirectly, the intervention of PBL during the learning process stimulates students to enlarge their critical thinking of them. Additionally, several empirical studies also reported that the intervention of PBL significantly improves students' critical thinking in a few countries such as Indonesia, Turkey, Spain, Malaysia, and Mexico (Chávez et al., 2020; Cobos-Torres et al., 2020; Ismail et al., 2018; Marthaliakirana et al., 2022; Ulger, 2018). Moreover, Rézio et al.

(2022) argued the PBL intervention assists significantly in enhancing students' critical thinking skills in mathematics, in which teachers and students have an important role in the implementation of PBL by which reflection, collaboration, and concepts discussion are essential constituents. The reports of theoretical and empirical studies provide strong evidence for this study in proposing that the PBL intervention effectively enhances students' critical thinking in mathematics from all school geographical locations such as metropolitan, urban, and rural areas.

From now on, this study found that school geographical location was not a significant moderating factor affecting students' heterogeneous MCTS in mathematics learning using PBL. This result indicates that the difference in students' MCTS is not due to the factor of school geographical location. It means there is no difference in MCTS between metropolitan, urban, and rural students who learn mathematics using PBL. This finding is in line with Suparman, Juandi, & Tamur (2021a), who revealed that students' heterogeneous MCTS who follow mathematics learning using PBL is not affected by the factor of research region in which there are no different MCTS between students who learn in western Indonesian region and students who learn in the eastern Indonesian region. These reports show that the factor of school geographical location does not have the leading role in causing students' MCTS to be different in mathematics learning implementing PBL.

In contrast, Nugraha & Suparman (2021a) reported that the factor of research region significantly affects the heterogeneous MCTS of Indonesian primary students who learn using PBL. There are significantly different MCTS between students who learn in the eastern and western areas. The results reported by Nugraha & Suparman (2021a) are different from those of the two previous studies because Nugraha & Suparman (2021a) only focused on the students' heterogeneous MCTS at the primary school level. In contrast, this study and the results reported by Suparman, Juandi, & Tamur (2021a) focused on the students' heterogenous MCTS in each educational level encompassing the primary school, the secondary school, and even the university/college.

In addition, this study reported that the effect size of PBL intervention on metropolitan students' critical thinking skills in mathematics was slightly larger than urban and rural students' critical thinking in mathematics. This indicates that by following the mathematics learning using PBL, students' MCTS in the metropolitan area is slightly greater than students' MCTS in the urban and rural areas. Consequently, the intervention of PBL for mathematics learning is more effective in being implemented in metropolitan areas than in urban and rural areas in enhancing students' MCTS. In a relevant study, Nugraha & Suparman (2021a) revealed that the effect size of the PBL intervention for the primary students' MCTS in the western region of Indonesia is moderately larger than the MCTS of primary students in the eastern region of Indonesia. In addition, Suparman, Juandi, & Tamur (2021a) also revealed the effect size of PBL intervention in Indonesia, showing that the MCTS of students in the eastern area is lower than students' MCTS in the western area. These findings claimed that the PBL intervention in enhancing students thinking critically in mathematics is more effective to be implemented in the western region than in the eastern area of Indonesia. Hernawati et al. (2017) stated that there are many metropolitan areas in the western Indonesian region. It indicates that the evidence of two previous meta-analysis studies strengthens this study's results that in enhancing students'

MCTS, the PBL intervention is more effective to be implemented in the metropolitan area than the urban and rural areas.

In the educational field, the competent teacher is one of the prominent factors in deciding the students' success in following the learning process. Tugirinshuti et al. (2022) argued that teachers have an essential role in facilitating and supporting students in learning. An empirical study reported no significant differences in competence between urban and rural teachers (Mohan et al., 2019). It indicates that urban and rural teachers have the same competence to facilitate students in following the learning process. No significant difference in competence among teachers based on geographical location can be one of the reasons for this study that revealed that there is no difference in MCTS among urban and also rural students who attend the learning of mathematics with the intervention of PBL.

Moreover, Safer-Lichtenstein et al. (2021) reported no significant difference in academic performance between rural and urban students. Furthermore, the facilities and infrastructures are important in supporting the educational process (Chand & Mohan, 2019; Guo et al., 2022). Specifically, Guo et al. (2022) revealed no obvious difference regarding the facilities and infrastructures between metropolitan and urban schools. It interprets that metropolitan or urban students can get adequate facilities and infrastructures such as classrooms, teachers, learning resources, and laboratories. It indicates that no significant difference in facilities and infrastructures based on the school's geographical location can be one of the reasons for this study that revealed no difference in MCTS between metropolitan students and urban students who follow mathematics learning using the intervention of PBL.

Implication and Suggestion

This study synthesizes no significant difference in MCTS among students who follow the mathematics learning process in any school location using the intervention of PBL. A few essential factors in the educational field, such as teacher competencies and school facilities and infrastructures, have a notable role in determining the student's academic success performance in the learning process. in which this study denotes that there is no prominent difference in teacher competencies and school facilities and infrastructures in any geographical location that affect no significant difference of MCTS among metropolitan students, urban students, and rural students. It implies that the Indonesian government must conduct the equable distribution of competent teachers in every school geographical location. As a result, students have the same opportunity to learn mathematics taught by competent teachers. Educational policies, such as conducting the equable distribution of competent teachers, can be realized by providing scholarships for teachers to continue their studies or training to improve and upgrade their competence suitable to the current development. In addition, the Indonesian government must ensure that the facility and infrastructure of Indonesian schools have entirely been completed in any geographical location in implementing the educational process. Consequently, students have the same facilities and infrastructures for learning mathematics. The Indonesian government can implement a bigger portion of the Indonesian state budget in building and completing the facilities and infrastructures of schools in each geographical location.

CONCLUSIONS

Most studies related to PBL and MCTS reveals that the PBL intervention has a strong positive effect on students to think critically in mathematics from all geographical location, such as metropolitan, urban, and rural area. However, a few studies report that the PBL implementation could not enhance the MCTS of metropolitan, urban, and rural students. However, the studies state that the intervention of the PBL is significantly enhanced for all metropolitan, urban, and rural students' MCTS. The PBL intervention has a strong positive effect on metropolitan and urban students' MCTS, while on rural students' MCTS, PBL intervention has a moderate positive effect. It indicates that the PBL intervention is more effective in improving thinking critically in mathematics in all schools with different geographical locations. Furthermore, school geographical location is not a significant moderating factor that affects students' heterogeneous MCTS, which interprets that there is no difference in MCTS between metropolitan, urban, and rural students who learn mathematics using PBL.

ACKNOWLEDGMENT

This research was financially supported by the Indonesian Educational Endowment of Fund (LPDP).

AUTHOR CONTRIBUTIONS STATEMENT

SS identified and established the research problems, decided on the inclusion criteria, and searched and selected the document/literature. Meanwhile, DJ coded the data from every document to the coding sheet, and BAP analyzed the data. All authors collectively wrote this manuscript.

REFERENCES

Alghafri, A. S. R., & Ismail, H. N. Bin. (2014). The effects of integrating creative and critical thinking on school students' thinking. *International Journal of Social Science and Humanity*, *4*(6), 518–525.

Arifin, S., Setyosari, P., Sa'dijah, C., & Kuswandi, D. (2020). The effect of problem-based learning by cognitive style on critical thinking skills and students' retention. *Journal of Technology and Science Education*, *10*(2), 271–281.

Bellamy, C. (2007). Online democratic deliberation in a time of information abundance. *Fast Capitalism*, *2*(2), 121–126.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. John Willey and Son Ltd.

Chand, D., & Mohan, P. (2019). Impact of school locality on teaching and learning: A qualitative inquiry. *Waikato Journal of Education*, *24*(2), 65–72.

Chávez, D. A., Gamiz-Sanchez, V. M., & Vargas, A. C. (2020). Problem-based learning: Effects on academic performance and perceptions of engineering students in computer sciences. *Journal of Technology and Science Education*, *10*(2), 306-328.

Cleophas, T. J., & Zwinderman, A. H. (2017). *Modern meta-analysis: Review and update of methodologies*. Springer International Publishing.

Cobos-Torres, J. C., Reyes, P. A., & Mendez, C. F. (2020). Problem-based learning for an electrical machines course. *International Journal of Emerging Technologies in Learning*, *15*(22), 192–203.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge Taylor & Francis Group.

Cooper, H. M., Patall, E. A., & Lindsay, J. J. (2013). Research synthesis and meta-analysis. In L. Bickman & D. J. Rog (Eds.), *The SAGE handbook of applied social research methods* (pp. 344–370). Sage Publications Inc.

Cumming, G. (2012). *Understanding the new statistics: Effect sizes, confidence intervals, and meta-analysis*. Routledge Taylor & Francis Group.

Du, X., Emmersen, J., Toft, E., & Sun, B. (2013). PBL and critical thinking disposition in Chinese medical students – A randomized cross-sectional study. *Journal of Problem Based Learning in Higher Education*, *1*(1), 72–83.

Epafras, L. C., Djalong, F. A., & Kaunang, H. P. (2019). Beyond signal and noise: Academics goes hoax and hoaxtivism. *Kawistara*, *8*(3), 213–309.

Falch, T., Lujala, P., & StrØm, B. (2013). Geographical constraints and educational attainment. *Regional Science and Urban Economics*, *43*(1), 164–176.

Fuad, M., Suyanto, E., Sumarno, Muhammad, U. A., & Suparman. (2022). A bibliometric analysis of technology-based foreign language learning during the COVID-19 pandemic: Direction for Indonesia language learning. *International Journal of Information and Education Technology*, *12*(10), 983–995.

Fuadi, D. S., Suparman, S., Juandi, D., & Avip Priatna Martadiputra, B. (2021). Technology-assisted problem-based learning against common problem-based learning in cultivating mathematical critical thinking skills: A meta-analysis. *ACM International Conference Proceeding Series*, 162–168.

Guo, F., Duan, Y., He, S., Zhang, Q., Xu, Q., & Miao, S. (2022). An empirical study of situational teaching: Agricultural Location in high school geography. *Sustainability*, *14*(14), 1–28.

Hendriana, H., Sumarmo, U., & Rohaeti, E. E. (2013). Kemampuan komunikasi matematis dan kemampuan berpikir kritis matematis. *Delta-Pi: Jurnal Matematika dan Pendidikan Matematika*, *2*(1), 35–45.

Hernawati, K., Insani, N., Bambang, S. H. M., Nur Hadi, W., & Sahid. (2017). Mapping the Indonesian territory, based on pollution, social demography and geographical data, using self organizing feature map. *AIP Conference Proceedings*, *1868*, 1–12.

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analysis. *British Medical Journal*, *327*, 557–560.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational Psychology Review*, *16*(3), 235–266.

Horswill, R. A. (2011). *The effects of school building condition and school geographical location on student achievement in Alberta*. University of Phoenix.

Hung, W. (2015). Problem-based learning: Conception, practice, and future. In *Authentic problem-solving and learning in the 21st century* (pp. 75–92). Springer.

Hunter, J. E., & Schmidt, F. L. (2004). *Methods of meta-analysis: Correcting error and bias in research findings* (2nd ed.). Sage Publications Inc.

Islahuddin, Ilyas, M., Basir, F., & Amini, S. F. (2018). Peningkatan kemampuan berpikir kritis matematika siswa dan habits of mind (striving for accuracy) melalui pembelajaran berbasis masalah. *Proximal: Jurnal Penelitian Matematika dan Pendidikan Matematika*, *1*(2), 107–116.

Ismail, N. S., Harun, J., Zakaria, M. A. Z. M., & Salleh, S. M. (2018). The effect of Mobile problem-based learning application DicScience PBL on students' critical thinking. *Thinking Skills and Creativity*, *28*, 177–195.

Jaya, A., & Suparman, S. (2021). The use of CABRI software in mathematics learning for cultivating geometrical conceptual understanding: A meta-analysis. *ACM International Conference Proceeding Series*, 37–44.

Juandi, D., Suparman, Martadiputra, B. A. P., Tamur, M., & Hasanah, A. (2022). Does mathematics domain cause the heterogeneity of students' mathematical critical thinking skills through problem- based learning? A meta-analysis. *AIP Conference Proceedings*, *070028*, 1–8.

Juandi, D., & Tamur, M. (2021). The impact of problem-based learning toward enhancing mathematical thinking: A meta-analysis study. *Journal of Engineering Science and Technology*, *16*(4), 3548–3561.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions:explanation and elaboration. *Journal of Clinical Epidemiology*, *62*(10), 1-10.

Lipsey, M. W., & Wilson, D. (2001). *Applied social research methods series*. Sage Publications Inc.

Liu, Z. K., He, J., & Li, B. (2015). Critical and creative thinking as learning processes at top-ranking Chinese middle schools: possibilities and required improvements. *High Ability Studies*, *26*(1), 139–152.

Marinda, H., Noer, S. H., & Asnawati, R. (2018). Penerapan model pembelajaran berbasis masalah untuk meningkatkan kemampuan berpikir kritis matematis dan self-confidence siswa. *Jurnal Pendidikan Matematika Unila*, *6*(6), 559–570.

Marthaliakirana, A. D., Suwono, H., Saefi, M., & Gofur, A. (2022). Problem-based learning with metacognitive prompts for enhancing argumentation and critical thinking of secondary school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(9), 21-32.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemica Medica*, *22*(3), 276–282.

Mike, W., & Cheung, L. (2015). *Meta-analysis: A structural equation modeling approach*. John Willey and Son Ltd.

Mohan, P. P., Swabey, K., & Kertesz, J. (2019). A comparative study of urban, rural and remote teachers' de-privatised practices. *Waikato Journal of Education*, *24*(2), 83–94.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ (Online)*, *339*(7716), 332–336.

Musa, A. (2013). Gender, geographic locations, achievement goals and academic performance of secondary school students from Borno State, Nigeria. *Research in Education*, *90*(1), 15–31.

Muzayanah, I. F. U., Nazara, S., Mahi, B. R., & Hartono, D. (2020). Is there social capital in cities? The association of urban form and social capital formation in the metropolitan cities of Indonesia. *International Journal of Urban Sciences*, *24*(4), 532–556.

Nargundkar, S., Samaddar, S., & Mukhopadhyay, S. (2014). A guided problem-based learning (PBL) approach: Impact on critical thinking. *Decision Sciences Journal of Innovative Education*, *12*(2), 91–108.

Neber, H., & Neuhaus, B. J. (2013). Creativity and problem-based learning (PBL): A neglected relation. In *Creativity, talent and excellence* (pp. 43–56). Springer.

Newman, M. J. (2005). Problem-based learning: An introduction and overview of the key features of the approach. *Journal of Veterinary Medical Education*, *32*(1), 12–20.

Noer, S. H., & Gunowibowo, P. (2018). Efektivitas problem-based learning ditinjau dari kemampuan berpikir kritis dan representasi matematis. *Jurnal Penelitian dan Pembelajaran Matematika*, *11*(2), 17–32.

Nugraha, T., & Suparman. (2021a). Does students' demography cause heterogeneity of students' mathematical critical thinking abilities through problem-based learning? A meta-analysis. *Journal of Hunan University (Natural Sciences)*, *48*(8), 47–55.

Nugraha, T., & Suparman, S. (2021b). Heterogeneity of Indonesian primary school students' mathematical critical thinking skills through problem-based learning: A meta-analysis. *Al-Jabar: Jurnal Pendidikan Matematika*, *12*(2), 315–328.

Oja, K. J. (2011). Using problem-based learning in the clinical setting to improve nursing students' critical thinking: An evidence review. *Journal of Nursing Education*, *50*(3), 145–151.

Pangeni, K. P. (2014). Factors determining educational quality: Student mathematics achievement in Nepal. *International Journal of Educational Development*, *34*(1), 30–41.

Putra, N. S., & Suparman. (2021). Problem-based learning: Its effect on student's critical thinking abilities in mathematics and sciences learning : A meta-analysis. *Journal of Hunan University (Natural Sciences)*, *48*(8), 163–171.

Ratnawati, D., Handayani, I., & Hadi, W. (2020). Pengaruh model pembelajaran PBL berbantu question card terhadap kemampuan berpikir kritis matematis siswa SMP. *Edumatica: Jurnal Pendidikan Matematika*, *10*(1), 44–51.

Rézio, S., Andrade, M. P., & Teodoro, M. F. (2022). Problem-based learning and applied mathematics. *Mathematics*, *10*(16), 1–13.

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2005). *Publication bias in meta-analysis: Prevention, assessment and adjustments*. John Willey and Son Ltd.

Safer-Lichtenstein, J., Reardon, K., & McIntyre, L. L. (2021). Does location matter? A single-state case study examining geographic differences in school-based ASD identification practices. *Journal of Applied School Psychology*, *37*(2), 185–196.

Sanders, S. (2016). Critical and creative thinkers in mathematics classrooms. *Journal of Student Engagement: Education Matters*, *6*(1), 19–27.

Sari, Y., Surya, E., & Asmin. (2020). The increasing of student's mathematics critical thinking ability through problem-based learning. *4th Annual International Seminar on Transformative Education and Educational Leadership*, *384*(Aisteel), 563–566.

Savery, J. R. (2006). Overview of PBL: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 9–20.

Suadi, M. H., Baker, R., Saudi, N. S. M., Ishak, N. I., & Sallehudin, H. (2021). An investigation of the school geographical location, peers influence, electronic media with absenteeism in high school. *Review of International Geographical Education*, *11*(1), 621–628.

Sulaiman, F., Coll, R. K., & Hassan, S. (2014). Effectiveness of PBL online on students' creative thinking: A case study in Malaysia. *Recent Advances in Educational Technologies and Methodologies*, 138–142.

Sumarmo, U., Hidayat, W., Zukarnaen, R., Hamidah, & Sariningsih, R. (2012). Kemampuan dan disposisi berpikir logis, kritis, dan kreatif matematis. *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam*, *17*(1), 17-31.

Sunaryo, Y. (2014). Model pembelajaran berbasis masalah untuk meningkatkan kemampuan berpikir kritis dan kreatif matematis siswa SMA di Kota Tasikmalaya. *Jurnal Pendidikan dan Keguruan*, *1*(2), 41–51.

Suparman, Juandi, D., & Martadiputra, B. A. P. (2021). Does treatment duration of problem-based learning moderate heterogeneity of students' mathematical critical thinking skills? A meta-analysis. *EduMa: Mathematics Education Learning and Teaching*, *10*(2), 206–221.

Suparman, Juandi, D., & Tamur, M. (2021a). Problem-based learning for mathematical critical thinking skills: A meta-analysis. *Journal of Hunan University (Natural Sciences)*, *48*(2), 133–144.

Suparman, Juandi, D., & Tamur, M. (2021b). Review of problem-based learning trends in 2010-2020 : A meta-analysis study of the effect of problem-based learning in enhancing mathematical problem-solving skills of Indonesian students. *Journal of Physics: Conference Series*, *1722*(012103), 1–9.

Suparman, Juandi, D., & Tamur, M. (2021c). Does problem-based learning enhance students' higher order thinking skills in mathematics learning? A systematic review and meta-analysis. *The 4th International Conference on Big Data and Education*, 44–51.

Suparman, S., Juandi, D., & Herman, T. (2021). Achievement emotions of female students in mathematical problem-solving situations. *Journal of Physics: Conference Series*, *1806*(1), 1–7.

Suparman, Suparman, Juandi, D., & Martadiputra, B. A. P. (2021). Heterogeneity of students' mathematical critical thinking ability re-viewed from education levels: A meta-analysis. *Paedagogia: Jurnal Penelitian Pendidikan*, *24*(2), 126–143.

Suparman, Tamur, M., Yunita, Wijaya, T. T., & Syaharuddin. (2021). Using problem-based learning to enhance mathematical abilities of primary school students: A systematic review and meta-analysis. *JTAM (Jurnal Teori dan Aplikasi Matematika)*, *5*(1), 144–161.

Tayyaba, S. (2012). Rural-urban gaps in academic achievement, schooling conditions, student, and teachers' characteristics in Pakistan. *International Journal of Educational Management*, *26*(1), 6–26.

Torp, L., & Sage, S. (2002). *Problems as possibilities: Problem-based learning for K–16 education* (2nd ed.). Association for Supervision and Curriculum Development.

Tugirinshuti, G. J., Mugabo, L. R., & Banuza, A. (2022). Video-based multimedia on learners' attitude towards astrophysics: Gender equity and school location. *International Journal of Evaluation and Research in Education*, *11*(3), 1455–1463.

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-based Learning*, *12*(1), 5-12.

Wechsler, S. M., Saiz, C., Rivas, S. F., Vendramini, C. M. M., Almeida, L. S., Mundim, M. C., & Franco, A. (2018). Creative and critical thinking: Independent or overlapping components?. *Thinking Skills and Creativity*, *27*, 114–122.

Widada, W., Sarwoedi, S., & Herawaty, D. (2019). Pengaruh problem-based learning berbasis etnomatematika Rejang Lebong terhadap kemampuan berpikir kritis siswa SMA. *Annals of Mathematical Modeling*, *1*(1), 31–34.

Yew, E. H. J., & Goh, K. (2016). Problem-based learning: An overview of its process and impact on learning. *Health Professions Education*, *2*(2), 75–79.

Yohannes, Juandi, D., & Diana, N. (2020). The evaluation of problem-based learning model towards high school students' critical thinking skills: A meta-analysis study in Indonesia. *The 12th International Conference on Education Technology and Computers*, 199–204.

Yohannes, Y., Juandi, D., & Tamur, M. (2021). The effect of problem-based learning model on mathematical critical thinking skills of junior high school students: A meta-analysis study. *Jurnal Pengukuran Psikologi dan Pendidikan Indonesia (JP3I)*, *10*(2), 142–157.