Enhancing Spatial Visualization in CABRI 3D-Assisted Geometry Learning: A Systematic Review and Meta-Analysis

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***Abstract*—Empirical studies related to the enhancement of spatial visualization by implementing CABRI 3D-assisted geometry lesson have been increasingly conducted in two last decade. Nevertheless, from these studies, it can be said that an inconsistent effect of CABRI 3D-assisted geometry lesson toward spatial visualization and a gap of students' spatial visualization are really existing. The aim of this present study is to examine the effectiveness of CABRI 3D-assisted geometry learning on spatial visualization, and some substantial factors in affecting the difference of students' spatial visualization skills. A systematic review using meta-analysis was performed to conduct this recent study in which the random effect model was selected to estimate the effect size computed by the Hedges' equation. 25 eligible documents published between 2008 and 2022 were included as the data whereby these documents generated 36 effect sizes and involved 2,440 students. Several tests, such as Z, Q Cochrane, fill and trim, and funnel plot were performed to analyze the data. Results of this current study showed that the utilization of CABRI 3D software for teaching geometry lesson had positive moderate effect ($g = 0.778$; $p < 0.05$), and significantly enhanced students' spatial visualization. Additionally, the investigation on some substantial factors revealed that intervention duration and class capacity were significant factors affecting the gap of spatial visualization of students while educational level and participant did not differentiate spatial visualization of students. This recent study implies that mathematics practitioners can utilize this software to teach geometry lesson, and consider small class for class capacity and more than 3 months for intervention duration in implementing it to enhance spatial visualization of students.**

***Keywords*—CABRI 3D, geometry learning, meta-analysis, spatial visualization, systematic review**

I. Introduction

Spatial visualization, one of essential abilities in solving mathematics problems, is not only extremely required for mathematics, but also other various scientific fields, such as science, technology, medicine, and technic [1]. Spatial visualization, in the process of mathematics learning, is applied to understanding geometry, in that it consists of visualization, rotation, and modelling [2]. National Council of Teachers of Mathematics (NCTM) [3] stated that every student must enhance spatial ability because the ability is useful in geometry field to solve mathematics problems, mainly regarding daily problems. According to Armah [4], geometry has an essential role in mathematics education in each of educational level. Moreover, it promotes the improvement of deductive thinking, spatial imagination, and basic of various mathematics and non-mathematics fields [5]. A few of empirical studies found that spatial visualization is an important part in understanding geometry concepts and solving geometry problems [6, 7]. Additionally, spatial visualization positively correlates to problem-solving in geometry [8]. Several studies also showed that the success of geometry achievement is the effective factor in spatial visualization skills [5, 9, 10]. This indicates that among others, those variables influence. It means that enhancing spatial visualization is going to help students in understanding geometry concepts and also geometry problems [11]. In addition, they more easily understand geometric objects and relation among objects [12].

The visualization is the main element of spatial ability, and can applied as a stimulant in the activity of geometry learning [13]. The geometry learning recommended to enhance spatial visualization is a learning utilizing technological media [14]. Therefore, integrating computer technology in the mathematics learning, particularly in geometry lesson will be important and well-known in dealing with the 21st challenging [15]. Dynamic Geometry Software (DGS) offers some specific software, such as CABRI 3D, GeoGebra, Geometers Sketchpad, and others [16]. Particularly, CABRI 3D refers to one of learning media which can explore spatial visualization. The utilization of this software in geometry lesson can be promoting media for mathematics teachers or lectures in enhancing students' spatial visualization. Geometry learning using this technological media enables students to manipulate three-dimensional objects and facilitate them in understanding geometry concepts and solving geometry problems [17]. According to Tejada and Serra [18], utilizing dynamic geometry media, like as CABRI 3D software, can decrease cognitive burden by using the visualization that is easier to be understood. This implies that the utilization of this software in geometry lesson can be a potentially alternative solution in enhancing students' spatial visualization skills, so they have extremely possible opportunities to get the high geometry achievement.

At least the last two decades, the empirical studies focusing on the improvement of spatial visualization of students by implementing CABRI 3D-assisted geometry lesson have been increasingly conducted. Some studies found that the use of this software in geometry lesson significantly enhances spatial visualization of students [7, 19–26]. Nevertheless, several other studies revealed that the utilization of this software in geometry lesson does not have significant impact on the enhancement of spatial visualization of students [2, 27–32]. These empirical studies indicate that an inconsistency of the effect of CABRI 3D-assisted geometry lesson on the improvement of students' spatial visualization skills is really existing. Consequently, the estimation and examination on the effectiveness of this software in geometry lesson to enhance spatial visualization

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have to be carried out to get the clear and precise conclusion, so that can provide the beneficial information related to this issue for mathematics practitioners, such as teacher and lecture.

Subsequently, of those empirical studies, some studies reported that to enhance students' spatial visualization, CABRI 3D-assisted geometry learning has positive moderate effect [21, 23, 24, 33], and even positive strong effect [20, 22, 25, 34, 35]. Few studies, however, reported that on the enhancement of students' spatial visualization, CABRI 3D-assisted geometry learning has positive modest effect [2, 26, 32], and even positive weak effect [29–31], and worse, negative effect [6, 28, 36]. These empirical reports interpret that there is a heterogeneous impact of the use of this software in geometry lesson to enhance spatial visualization of students. This indicates that the gap of spatial visualization of students in geometry lesson assisted by CABRI 3D software is really existing. As a consequence of this issue, the investigation and examination on some potential moderating variables, in particular substantial factors, such as class capacity, educational level, intervention duration, participant, and others are urgently needed to justify the involvement of these factors in affecting the difference of students' spatial visualization skills. From this, it can provide some suggestion or recommendation for educational policymaker, narrowly in school institution to decide the practical and effective regulations in promoting the enhancement of students' spatial visualization, so they can get the optimal geometry achievement.

The presentation of previously relevant studies shows that the utilization of CABRI 3D software in mathematics lesson and even specifically on geometry lesson relatively has not been focused on spatial visualization skills. Moreover, a few of previously relevant secondary studies present that the enhancement of spatial visualization of students specifically has not used the CABRI 3D as dynamic geometry software. As a consequence, this current meta-analysis study focuses on the improvement of spatial visualization of students utilizing this software in implementing geometry lesson. In addition, this recent study also focuses in investigating class capacity, educational level, intervention duration, and participant as the substantial factors in affecting the difference of spatial visualization of students in CABRI 3D-assisted geometry learning. The aim of this recent study is to examine the effectiveness of CABRI 3D-assisted geometry lesson toward the enhancement of spatial visualization of students, and the significance of several substantial factors, such as class capacity, intervention duration, participant, and educational level in affecting students' heterogeneous spatial visualization in the geometry lesson utilizing this software. The following research questions are directed to achieve the aims of this recent study, such as:

1) How much the effect size does CABRI 3D-assisted geometry learning have on students' spatial visualization?
2) Does CABRI 3D-assisted geometry learning enhance students' spatial visualization?
3) Do some substantial factors, such as educational level, intervention duration, class capacity, or participant affect the gap of students' spatial visualization in geometry classroom using CABRI 3D software?

II. Literature Review

A. Spatial Visualization

Explaining spatial visualization is inseparable from spatial ability, in that it is one of the elements of spatial ability. Kosa and Karakus [1] defined spatial ability as the ability in presenting, creating, recalling, and transforming symbol, non-linguistic information. Moreover, a few literatures stated that this ability refers to a skill in generating, retrieving, retaining, and transforming well-structured visual objects [37, 38]. On the other hand, Sutcu [39] explained that spatial ability is used to create visual objects stimulating our mind and manipulate these objects in the mind. Meanwhile, Guven and Kosa [19] argued that spatial ability is related to mental activities applied in creating, making, perceiving, recalling, storing, and arranging spatial objects. So, it can be said that spatial ability refers to a skill used to make spatial objects clear by passing various processes, such as presenting, transforming, generating, retaining, arranging, and others. Additionally, it has an essential part in both communication and scientific creativity [39]. Consequently, if students do not have a well-developed spatial visualization, they will meet serious problems influencing their geometry achievement, more general in mathematics.

Generally, spatial ability is categorized to be two elements, such as spatial relation and spatial visualization [1, 2, 19, 38]. Meanwhile, Alansari *et al*. [40] stated that this ability consists of spatial visualization, mental rotation, and spatial perception. Of those categories, this current study only focuses on spatial visualization, in that it is noticed to be one of the most essential sub-elements of spatial ability [39]. Indeed, spatial visualization is a main component of spatial ability, and can be applied as a strengthening stimulant to teach geometry lesson [2, 37]. A few literatures stated that spatial visualization refers to the skills in mentally manipulating, twisting, rotating, and inverting a pictorially presented stimulus [1, 2]. On the other hand, Park *et al*. [41] defined these skills as the ability to mentally imagine the rotation of depicted objects, the folding or unfolding of flat patterns, and the relative changes of object positions in space, and manipulate an entire spatial configuration. Particularly, Kusar [42] argued that spatial visualization consists of manual manipulation, mental manipulation, spatial creativity, and speed of object's manipulation. These elements are used to measure spatial visualization skills in each eligible document involved in this recent study.

B. Geometry and CABRI 3D Software

Geometry is an essential part of mathematics. NCTM [3] stated that mathematics as a scientific language contains some specific contents, such as data analysis and probability, geometry, measurement, algebra, number and operations. Geometry can help in promoting other mathematics parts, such as algebra, calculus, and statistics. Moreover, some concepts and problems in algebra, calculus, and number systems can be explained by geometric approach or perspective [29]. As a consequence of that, geometry concepts must be understood and geometry problems have to be solved by students. It implies to them in getting the maximum geometry achievement, in general on mathematics achievement. On the other hand, the technological development in the 21st century, especially in educational field, can be utilized to promote geometry learning. Several facts reveal that not all topic in geometry can be easily explained in the traditional way in which some of those need technological assistance [11, 13, 43]. Therefore, the utilization of technology, particularly computer technology in implementing geometry lesson, must be optimized in the environment of mathematics learning.

Regarding computer technology in mathematics learning, DGS can be an effective tool to teach geometry. The emergence of DGS has significantly changed the way to teach geometry [29]. This software allows teachers and students to make geometric objects, measure some variables, such as distance, angle, and surface area, provide geometric constructions, and drag numbers through the screen [43]. The DGS has several varieties, such as Geometer's Sketchpad, GeoGebra, CABRI 2D & 3D, Cinderella, WINGEOM, and others. Of those DGS's varieties, this recent study only focuses on the utilization of CABRI 3D software for promoting geometry lesson. This software is created to explore 3D objects in that it is believed to revolutionize computer-assisted visualization in 3D objects [2]. Particularly, Kosa [29] stated that CABRI 3D software provides an environment that makes students possible to explore geometric relationships, and create and examine the geometric conjectures. Moreover, Kosa and Karakus [9] argued that CABRI 3D software enables students or teachers to manipulate and construct geometry objects in three dimensions via a 2D interface. So, the utilization of this software for teaching geometry lesson has an important role on the improvement of spatial visualization.

C. The Evidence: Spatial Visualization and CABRI 3D Software

Many previously secondary studies using a systematic review and meta-analysis focused on either mathematics learning intervention and spatial visualization, or CABRI 3D software and mathematics achievement. Several meta-analysis studies revealed that the utilization of CABRI 3D software in mathematics learning had positive moderate effect on students' mathematics achievement [43–47]. Moreover, particularly a meta-analysis studies reported that the use of CABRI 3D software in geometry lesson had positive moderate effect on students' geometry achievement [48]. Meanwhile, Cavus and Deniz [49] found that the utilization of this software in geometry lesson had positive strong effect on students' geometry learning outcome. These reports show that mathematics learning, especially geometry lesson utilizing CABRI 3D software has positive moderate and even strong effect on students' mathematics achievement. Additionally, in a meta-analysis report focusing on spatial visualization, Hawes *et al*. [50] revealed that the intervention of mathematics lesson had positive modest effect on students' spatial visualization skills. On the other hand, Turgut and Turgut [51] reported that the spatial training had positive moderate effect on students' spatial visualization skills. These previous meta-analysis studies show that a few interventions such as mathematics learning and spatial training have positive modest and even moderate effect on students' spatial visualization skills. From these relevant meta-analysis reports, it can be hypothesized that the use of this software for teaching geometry lesson is effective in enhancing students' spatial visualization skills.

D. Potential Moderating Factor

The gap of students' spatial visualization skills in the learning environment filled in by CABRI 3D-assisted geometry learning indicates that there is the involvement of some potential moderating factors. Indirectly, these moderating factors affect the difference of students' spatial visualization skills. Consequently, a few students have high spatial visualization skills but other students have low spatial visualization skills, and also a lot of students have moderate spatial visualization skills. Therefore, it is extremely essential to investigate and examine the significance of those moderating factors in affecting students' heterogeneous spatial visualization. In a few literatures (e.g., Helsa *et al*. [52], Suparman and Juandi [53]), stated that generally, there are two characters of moderating factor such as substantial and extrinsic. Moreover, Helsa *et al*. [52] explained that substantial factor refers to the factors which are directly related to independent or dependent variable such as class capacity, gender, educational level, intervention duration, school geographical location, participant, and instrument. Meanwhile, extrinsic factor is the factors that do not relate to independent or dependent variable such as publication year, document type, source, and database. Particularly, this recent study focuses on the substantial factors to be investigated and examined in that those factors have an important role on the difference of students' spatial visualization skills.

A lot of relevant meta-analysis studies also had investigated and examined the involvement of some substantial factors such as class capacity [43, 45–48, 51], educational level [43–49, 51], intervention duration [44, 45, 48, 50, 51], student engagement [43, 45], instrument [45], geometry material [48], and participant [48]. Several studies found that some factors such as class capacity, educational level, intervention duration, student engagement, participant, and instrument were the significant factors affecting the gap of students' mathematics achievement in CABRI 3D-assisted mathematics learning [43–45, 47], the difference of students' geometry achievement in CABRI 3D-assisted geometry learning [48], and the heterogeneity of students' spatial visualization skills in spatial intervention [50]. A few studies, however, found that a few factors such as class capacity, educational level, intervention duration, and geometry material did not affect students' heterogeneous mathematics achievement in the mathematics learning using CABRI 3D software [46], the gap of students' geometry achievement in the geometry lesson using CABRI 3D software [48], and the difference of students' spatial visualization skills in spatial training [51]. From these relevant studies, it can be indicated that some substantial factors such as class capacity, educational level, intervention duration, and participant have a potential role in affecting the gap of students' spatial visualization skills in CABRI 3D-assisted geometry learning.

III. Methods

A. Research Design

To conduct this study, a systematic review using meta-analysis was performed. As an estimating model, the random effect model was selected in that all of empirically primary studies involved had some heterogeneities in research participant, educational level, class capacity, treatment duration, instrument, and others [52, 54]. In a literature, Cooper *et al*. [55] stated that there were seven stages in conducting a meta-analysis study (See Fig. 1).

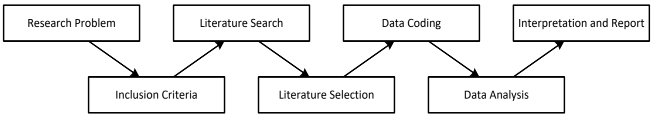

Fig. 1. The steps of meta-analysis.

B. Inclusion Criteria

Several inclusion criteria were set to restrict the problems of this recent meta-analysis study. The PICOS (Population, Intervention, Comparator, Outcome, & Study design) approach proposed by Moher *et al*. [56], was involved to decide the inclusion criteria. Those were such as (1) the population in the document was Indonesian and also foreign students in each educational level from elementary school until university/college; (2) the intervention in the document was CABRI 3D-assisted geometry learning; (3) the comparator in the document was traditional geometry learning; (4) the outcome in the document was spatial visualization skills; (5) the study design in the document was quasi-experiment research using post-test only control group design; (6) the document was published between 2001 and 2022 whereby it was indexed by Scopus and Google Scholar; (7) the document type was article and conference paper; and (8) the document reported the sufficient statistical data to calculate the effect size. Consequently, the document which was not suitable to the inclusion criteria would be excluded as the data in the selection process.

C. Document Search and Selection

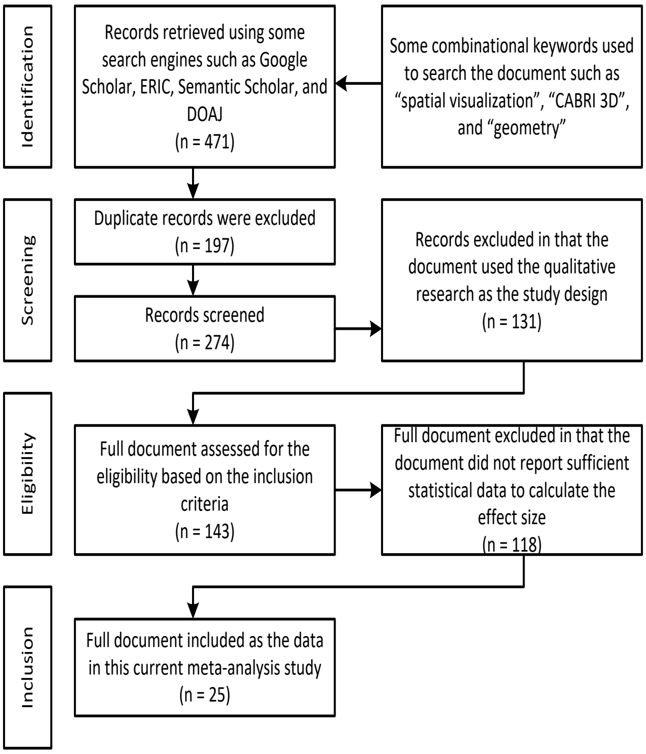

Fig. 2. PRISMA flow-chart of document selection of this meta-analysis study.

Few search engines such as Google Scholar, ERIC, Semantic Scholar, and DOAJ were utilized to find the document. Moreover, some combinational keywords such as "spatial visualization", "CABRI 3D", and "geometry" were used to make easy the search of document in those search engines. Some literatures stated that there were four stages to select the document systematically such as (1) identification, (2) screening, (3) eligibility, and (4) inclusion [48, 57–60]. The process of document selection is presented in Fig. 2.

D. Data Coding

The coding sheet was used as the instrument to extract the data from each document. Generally, the data consisted of statistical data, categorical data, and supplementary data. Particularly, the statistical data was such as mean, sample size, standard deviation, t-value, and p-value. Meanwhile, the categorical data was such as class capacity, educational level, intervention duration, and participant. Additionally, some information such as author, indexer, publication year, document type, source, email, and tracing link were included in supplementary data. Moreover, the categorical data were the moderating factors whereby in detail, these factors are described in Table 1.

Table 1. The distribution of documents based on moderating factors

Moderating Factors	Groups	Document Frequency	Percentage
Class Capacity	n ≤ 30 (Small Class)	6	24%
	n > 30 (Large Class)	19	76%
Educational Level	Elementary School	3	12%
	Middle School	11	44%
	High School	6	24%
	University/College	5	20%
Intervention Duration	1 Month	3	12%
	3 Months	9	36%
	More than 3 Months	13	52%
Participant	Indonesian Student	16	64%
	Foreign Student	9	36%

The process in coding the data involved two experts in meta-analysis study in which they were statistics lecture. This was carried out to ensure that the data extracted from each document to the coding sheet was valid and credible to be used [53, 61, 62]. To conduct it, Cohen's Kappa test was performed. McHugh [63] stated that the measurement of Cohen's Kappa was formulated as follows:

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

Particularly, Pr(a) was the relative observed agreement among raters while Pr(e) was the hypothetical probability of chance agreement. The Kappa value was classified as 0.00 – 0.20 (None), 0.21 – 0.39 (Minimal), 0.40 – 0.59 (Weak), 0.60 – 0.79 (Moderate), 0.80 – 0.90 (Strong), and 0.91 – 1.00 (Almost Perfect) [63]. The results of Cohen's Kappa test on statistical data and categorical data are shown in Table 2.

From Table 2, it can be seen that all of significant values of Cohen's Kappa test on those items were less than 0.05 whereby it indicates that those coders significantly agree toward the statistical and categorical data extracted from each document to the coding sheet. Moreover, it means that the statistical and categorical data verified by those coders are valid and credible to be used and then analyzed [64–66].

Table 2. The results of Cohen's Kappa test

Items	Kappa Value	Agreement Level	Sig.
Authors	0.912	Almost Perfect	0.006
Mean of Experiment Group	0.954	Almost Perfect	0.002
Deviation Standard of Experiment Group	0.937	Almost Perfect	0.004
Sample Size of Experiment Group	0.961	Almost Perfect	0.001
Mean of Control Group	0.972	Almost Perfect	0.001
Deviation Standard of Control Group	0.948	Almost Perfect	0.003
Sample Size of Control Group	0.929	Almost Perfect	0.005
t-value	0.918	Almost Perfect	0.006
p-value	0.963	Almost Perfect	0.001
Class Capacity	0.899	Strong	0.011
Educational Level	0.817	Strong	0.027
Intervention Duration	0.826	Strong	0.019
Participant	0.865	Strong	0.016

E. Data Analysis

To compute the effect size, the Hedge's equation was used in that it facilitated the empirical studies which had relatively small sample size [52]. According to Borenstein *et al*. [67], the Hedge's equation could be formulated as follows:

$$g = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}} \times \left(1 - \frac{3}{4df - 1}\right)$$

Particularly, $\overline{x_1}$ represents the mean of geometry classroom using GeoGebra software while $\overline{x_2}$ represents the mean of geometry classroom which do not use GeoGebra software. Moreover, S_1^2 represents the deviation standard of geometry classroom using GeoGebra software while S_2^2 represents the mean of geometry classroom which do not use GeoGebra software. Additionally, n_1 represents the sample size of geometry classroom using GeoGebra software while n_2 represents the mean of geometry classroom which do not use GeoGebra software. Meanwhile, *df* represents degree of freedom.

The effect size in g unit was categorized as 0.00–0.20 (weak), 0.21–0.50 (modest), 0.51–1.00 (moderate), and >1.00 (strong) [68]. Furthermore, the Z test was performed to examine the significance of CABRI 3D-assisted geometry learning on students' spatial visualization skills [53, 54]. Additionally, the Cochran's Q test was carried out to investigate and examine the involvement of those moderating factors in affecting the gap of students' spatial visualization skills in CABRI 3D-assisted geometry learning [61, 62].

In a literature, Cooper *et al*. [55] stated that the statistical data in the meta-analysis study tended to become publication bias. Publication bias was a condition in which researchers relatively reported the significant results of their empirical studies, whereas actually the reports did not show the significant results of experimental intervention. Consequently, few tests such funnel plot analysis and fill and trim test were applied to make sure that before the valid and credible data were analyzed, those were avoided from the publication bias [48, 59]. Particularly, the funnel plot was used to detect the publication bias in that it could describe the distribution of effect size data, so it could be detected the unlogic effect size that appeared in the plot. Subjectively, the symmetry of effect size distribution drew that there was no indication of publication bias in that there was no effect size data which be outliers. Additionally, fill and trim test was conducted by identifying the existence of effect size data that had to be excluded in which if the value showed 0, there was no outliers in the distribution of effect size data. Moreover, Bernard *et al*. [69] also argued that the set of effect size tended to be sensitive on the change of the data quantity. As consequence, sensitivity analysis had to be conducted to ensure that the set of effect size data was not sensitive. The tool "one study removed" in Comprehensive Meta-Analysis (CMA) software was utilized to do it. All of calculations in this current study used CMA software version 3.0.

IV. Results

A. Publication Bias and Sensitivity Analysis

The funnel plot analysis was used to describe the distribution of effect size data in the plot (See Fig. 3). From the distribution, it could be subjectively seen the symmetry of a set of effect size data.

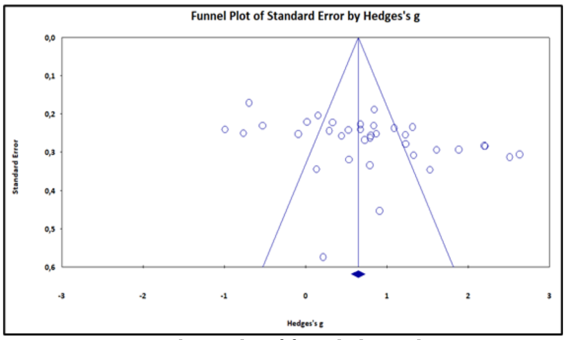

Fig. 3. The results of funnel plot analysis.

From Fig. 3, it can be seen that the distribution of effect size data in the funnel plot was symmetrical. This interprets that the statistical data used to compute the effect size does not have the indication of publication bias. According to Jaya and Suparman [48], the symmetrical distribution of a set of effect size data in the funnel plot indicates that there is no publication bias to the statistical data.

Moreover, the fill and trim test was performed to justify the symmetry of a set of effect size data in the funnel plot (See Table 3).

Table 3. The results of fill and trim test

	Studies Trimmed	Effect Size in g Unit	Q-value
Observed Values		0.7784 [0.4918; 1.0648]	398.16
Adjusted Values	0	0.7784 [0.4918; 1.0648]	398.16

Table 3 shows that there was no data of effect size that had to be excluded from the set of effect size data. It means that absolutely the distribution of effect size data in the funnel plot is indeed symmetrical. This provides strong evidence that the statistical data involved in this recent study to measure the effect size is eluded from the phenomenon of publication bias.

The sensitivity of effect size data had to be verified to ensure the volatility of the data. The utilization of tool "one study removed" in CMA software shows that the lowest g unit was 0.726 and the highest g unit was 0.830. Meanwhile, the average of effect size in g unit was 0.778. This means that the average of effect size is located in the interval between 0.726 and 0.830 whereby it indicates that the set of effect size data is not sensitive to the change of data quantity. In a literature, Bernard *et al*. [69] also stated that when the interval between the lowest effect size and the highest effect size contains the average of effect size, the change of data quantity does not affect the sensitivity of effect size data.

B. Summary and Estimation of Effect Size

The computation of the statistical data using the Hedge's equation generated several heterogeneous effect sizes, from negative to positive, and also from weak until strong (See Table 4).

Table 4. The results of summary and estimation of effect size

Document	Effect Size in g Unit	Z-value	P-value
Nurjanah *et al*. [24]	0.675 [0.201; 1.148]	2.793	0.005
Kariadinata *et al*. [22]	1.332 [0.727; 1.936]	4.315	0.000
Chang *et al*. [23]	0.730 [0.204; 1.256]	2.720	0.007
Guven & Kosa [19]	0.676 [0.229; 1.122]	2.967	0.003
Guven & Kosa [19]	0.840 [0.387; 1.293]	3.635	0.000
Guven & Kosa [19]	1.090 [0.624; 1.556]	4.587	0.000
Yilmaz [25] 2015a	2.203 [1.646; 2.760]	7.752	0.000
Yilmaz [25]	2.211 [1.654; 2.769]	7.770	0.000
Yilmaz [25]	2.636 [2.035; 3.237]	8.596	0.000
Karakus & Peker [28]	−0.089 [−0.585; 0.408]	−0.350	0.727
Hendriana *et al*. [35]	1.231 [0.731; 1.730]	4.831	0.000
Baki *et al*. [2]	0.291 [−0.189; 0.771]	1.189	0.234
Baki *et al*. [2]	0.806 [0.301; 1.310]	3.129	0.002
Kosa [29]	0.154 [−0.248; 0.556]	0.751	0.452
Hannafin *et al*. [20]	1.888 [1.312; 2.464]	6.423	0.000
Boyraz *et al*. [27]	0.534 [−0.092; 1.160]	1.671	0.095
Boyraz *et al*. [27]	0.792 [0.136; 1.448]	2.366	0.018
Nasution [33]	0.797 [0.282; 1.313]	3.032	0.002
Syahputra [26]	2.513 [1.899; 3.127]	8.018	0.000
Syahputra [26]	0.334 [−0.103; 0.771]	1.499	0.134
Syahputra [26]	0.912 [0.023; 1.802]	2.010	0.044
Syahputra [26]	0.847 [0.477; 1.217]	4.486	0.000
Syahputra [26]	0.217 [−0.910; 1.344]	0.378	0.705
Napitupulu *et al*. [21]	0.871 [0.375; 1.366]	3.445	0.001
Aziz *et al*. [8]	1.316 [0.856; 1.776]	5.605	0.000
Hartatiana *et al*. [6]	−0.991 [−1.463; −0.518]	−4.107	0.000
Hartatiana *et al*. [6]	−0.766 [−1.258; −0.274]	−3.051	0.002
Hartatiana *et al*. [6]	−0.696 [−1.031; −0.360]	−4.059	0.000
Yuliardi *et al*. [36]	−0.529 [−0.982; −0.076]	−2.289	0.022
Ma'sum *et al*. [30]	0.019 [−0.415; 0.454]	0.088	0.930
Adirakasiwi & Warmi [34]	1.614 [1.037; 2.191]	5.483	0.000
Lin & Chen, [37]	0.135 [−0.542; 0.811]	0.391	0.696
Pramudiyanti *et al*. [32]	0.443 [−0.063; 0.949]	1.717	0.086
Kepceoglu [11]	0.528 [0.053; 1.003]	2.179	0.029
Dere & Kalelioglu [13]	1.233 [0.687; 1.779]	4.427	0.000
Muntazhimah & Miatun [7]	1.532 [0.853; 2.210]	4.425	0.000
Estimated Effect Size	0.778 [0.492; 1.065]	5.326	0.000

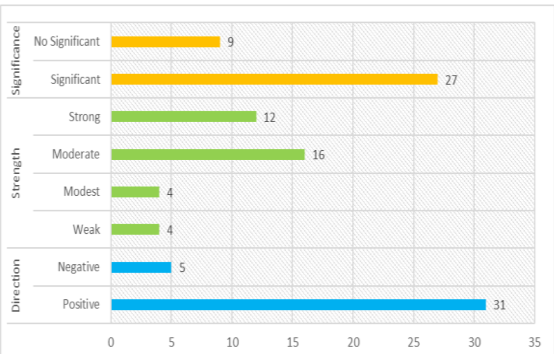

Fig. 4. The frequency distribution of effect size data based on significance, strength, and direction.

From Table 4, it can be seen that 25 valid and credible documents generated 36 effect sizes in that there were two documents resulting two effect sizes (e.g., Baki *et al*. [2], Boyraz [27]), followed by three documents resulting three effect sizes (e.g., Guven & Kosa [19], Hartatiana *et al*. [70], Yilmaz [25]) and one document resulting five effect sizes (e.g., Syahputra, [26]).

Additionally, those effect sizes could be categorized to be three characters based on direction, strength, and significance. The frequency distribution of effect size data based on these characters is presented in Fig. 4.

From Fig. 4, it can be seen that the data of effect size viewed by the direction consisted of 13.89% negative effect size and 86.11% positive effect size. In addition, the data of effect size viewed by the significance consisted of 25% no significant effect size and 75% significant effect size. Meanwhile, the data of effect size viewed by the strength contained in 11.11% weak effect size, 44.44% moderate effect size, 11.11% modest effect size, and 33.33% strong effect size. These show that the data of effect size is dominated by significant, positive, and moderate effect size. Fig. 4 also shows that the estimated effect size was 0.778 whereby it interprets that CABRI 3D-assisted geometry learning has positively moderate effect on students' spatial visualization skills. Moreover, the estimated significance value of the Z test was less than 0.05. This shows that the utilization of this software in geometry learning significantly enhances students' spatial visualization skills. In another interpretation, it indicates that CABRI 3D-assisted geometry learning is effective in enhancing students' spatial visualization skills.

C. Subgroup Analysis

This analysis was used to investigate deeply and test the involvement of several substantial factors, such as class capacity, intervention duration, educational level, and participant in affecting the gap of spatial visualization of students in the geometry learning utilizing this software. From Table 5, it can be seen that the estimated significance value of the Q Cochrane test for a few factors such as class capacity and intervention duration was less than 0.05. This interprets that class capacity and intervention duration significantly affect the gap of spatial visualization of students in CABRI 3D-assisted geometry learning. Meanwhile, the estimated significance value of the Q Cochrane test for some substantial factors, such as participant and educational level was more than 0.05. This interprets that participant and educational level are not the factors affecting the gap of spatial visualization of students in the geometry learning using this software.

Table 5. The results of the Q Cochrane test

Moderating Factor	Group	Effect Size in g Unit	Heterogeneity		
			Q-value	df(Q)	P-value
Class Capacity	n ≤ 30 (Small Class) n > 30 (Large Class)	0.945 0.728	1.238	1	0.048
Educational Level	Elementary School Middle School High School University/College	0.706 0.569 0.692 1.067	1.577	3	0.665
Intervention Duration	1 Month 3 Months More than 3 Months	0.511 0.647 1.019	1.853	2	0.041
Participant	Indonesian Student Foreign Student	0.628 0.987	1.524	1	0.217

V. DISCUSSION

A. The Effect of the Use of CABRI 3D Software in Geometry Learning on Students' Spatial Visualization Skills

The present study reveals that the geometry lesson utilizing CABRI 3D software had positive moderate effect on the enhancement of spatial visualization of students. This is similar to some relevant studies reporting that CABRI 3D-assisted mathematics learning also had positive moderate effect toward the enhancement of students' mathematics achievement [43, 44, 46, 47]. In particular, a relevant study showed that the utilization of CABRI 3D software in geometry lesson also had positive moderate effect on students' geometry achievement [48]. Another relevant study also revealed that the spatial training had positive moderate effect in enhancing students' spatial visualization skills [51]. These relevant studies provide strong evidences that CABRI 3D-assisted geometry lesson has positive moderate effect on spatial visualization of students.

Moreover, the current study also shows that CABRI 3D-assisted geometry learning significantly affected the improvement of spatial visualization of students. It interprets that the utilization of this software for geometry lesson is effective in enhancing students' spatial visualization skills. Several previously relevant studies also revealed that the intervention of mathematics learning assisted by this software significantly enhanced students' mathematics achievement, particularly in geometry lesson [43, 46–48]. Additionally, a few of previously relevant studies showed that the intervention like as spatial training significantly improved students' spatial visualization skills [50, 51]. Those relevant reports strengthen the findings of this recent study that CABRI 3D-assisted geometry lesson is one of the effectively alternative interventions in improving spatial visualization of students.

Since the 1990s, CABRI 3D software as one of the DGS, beside GeoGebra, Geometers' Sketchpad and Cinderella, has been widely utilized for teaching geometry lesson. This software massively revolutionizes computer technology-assisted visualization in three-dimensional geometry objects, such as cone, pyramid, prism, and cylinder. It implies, particularly, this tool facilitates the enhancement of spatial visualization skills on students by implementing the geometry learning. In a literature, Kosa and Karakus [1] stated that spatial visualization is one of the main indicators of spatial ability, beside spatial perception, spatial orientation, mental rotation, and spatial relation. Spatial visualization had by students can promote them in understanding geometry concept and solving geometry problems [24]. More general, spatial visualization is required by a lot of other scientific fields such as architecture, biology, astronomy, chemistry, engineering, cartography, physics, geology, and music [39, 42]. As a consequence, the existence and development of CABRI 3D software are extremely needed to improve spatial visualization of students.

The intervention of geometry learning by utilizing CABRI 3D enables students to explore the component of 3D objects, such as plane, angle, and distance, in real situation. This is due to that CABRI 3D software presents an environment whereby they can investigate geometric relationships, and create and examine the conjectures [1]. Moreover, Baki *et al.* [2] argued that the unique feature of CABRI 3D software is the tool of 'dragging'. This feature makes easy students in exploring the legitimacy of specific conjectures on three-dimensional objects. It means that this tool facilitates explorations promoting the conjecture process. In detail, some 3D shapes, such as cylinder, cone, prism, and pyramids can be transformed in several activities, such as rotation, translation, reflection, and dilation [28, 29]. Through these activities, the three-dimensional shapes can be constructed and seen from a certain aspect on the screen. Additionally, a few measurements, such as surface area, distance, and angle can be calculated and obtained on the screen of this software in which this makes possible students to learn more the component of three-dimensional geometry objects [25, 31]. It can be said that the features on CABRI 3D software offer extraordinary opportunities for students to enhance their spatial visualization skills. Therefore, CABRI 3D-assisted geometry learning can effectively enhance students' spatial visualization skills.

B. Heterogeneity of Students' Spatial Visualization Skills in CABRI 3D-assisted Geometry Learning

The gap of students' spatial visualization skills in geometry lesson utilizing CABRI 3D software can be initiated by potential moderating factors, specifically substantial factors. The investigation of this present study has inferentially examined some substantial factors, such as class capacity, educational level, intervention duration, and participant. This current study shows that a few of substantial factors, such as intervention duration and class capacity were the significant factors in affecting the difference of students' spatial visualization skills in the geometry lesson by using CABRI 3D software. Meanwhile, other substantial factors such as educational level and participant were not the potential factors in affecting students' heterogeneous spatial visualization skills in CABRI 3D-assisted geometry learning. Each of substantial factor is discussed and explained in the following subsection.

1) Class capacity

The factor of class capacity in this current study was grouped to be two categories consisting of small class ($n \leq 30$ students) and large class ($n > 30$ students). This present study shows that class capacity was one of the significant factors affecting the gap of students' spatial visualization skills in the geometry lesson utilizing CABRI 3D software. This was similar to some relevant studies showing that the factor of class capacity significantly differentiated students' mathematics achievement in mathematics classroom assisted by CABRI 3D software [43, 47]. More specific, Jaya and Suparman [48] revealed that the gap of students' geometry achievement in CABRI 3D-assisted geometry learning was significantly affected by class capacity. In addition, Hawes *et al.* [50] also reported that class capacity significantly caused the difference of spatial visualization of students in the learning classroom using the intervention like as spatial training. These relevant reports justify that class capacity significantly differentiates spatial visualization of students in geometry classroom using this software.

In detail, the utilization of this software in geometry lesson had positive moderate effect on the enhancement of spatial visualization of students in small and large class. Nevertheless, the effect of CABRI 3D-assisted geometry lesson in small class was higher than the effect of CABRI 3D-assisted geometry lesson in large class. This indicates that the factor of class capacity, in CABRI 3D-assisted geometry learning, significantly creates the difference of spatial visualization skills between students who learn in small class and students who learn in large class. A few of relevant studies also showed that there was a different mathematics achievement in mathematics classroom utilizing CABRI 3D software among students who study in small class and large class [43, 47]. Additionally, Jaya and Suparman [48] revealed that there was also a different geometry achievement in geometry lesson using CABRI 3D software among students who learn in large and small class. From these relevant studies, it can be interpreted that mathematics teachers who teach geometry material by utilizing CABRI 3D software in small class have more opportunities like as a time than they teach geometry lesson by using CABRI 3D in large class. Consequently, they who teach geometry topic in small class can more facilitate and accommodate student needs in the learning process than they who teach it in large class.

2) Educational level

The factor of educational level in this recent study was categorized to be four groups consisting of elementary school, middle school, high school, and university/college. This present study reveals that educational level did not influence the difference of spatial visualization of students in the geometry lesson by using CABRI 3D software. A relevant study also showed that educational level did not differentiate students' geometry achievement in CABRI 3D-assisted geometry learning [48]. Ramadhanti and Juandi [46] also revealed that this factor was not a significant factor that caused the difference of students' mathematics achievement in mathematics classroom utilizing CABRI 3D software. Additionally, Turgut and Turgut [51] also revealed that the heterogeneity of students' spatial visualization skills in the intervention class implementing spatial training was not caused by the educational level. These relevant studies provide strong evidences that this factor does not has the involvement in differentiating students' spatial visualization skills in geometry lesson assisted by this software.

Particularly, the implementation of geometry lesson assisted by this software had positive moderate effect on spatial visualization of students in elementary, middle, and high school. Meanwhile, geometry classroom promoted by CABRI 3D software had positive strong effect on university/college students' spatial visualization. This interprets that the effect of CABRI 3D-assisted geometry lesson for enhancing students' spatial visualization skills in elementary, middle, and high school is higher than the effect of CABRI 3D-assisted geometry lesson for improving university/college students' spatial visualization skills. It means that the utilization of this software to teach geometry lesson is more effective in improving students' spatial visualization in elementary, middle, and high school than university/college students' spatial visualization. Moreover, the factor of educational level was not involved in affecting the gap of students' spatial visualization to indicate that the instrument applied to measure spatial visualization in each of educational level has been suitable to students' cognitive development. As a consequence, there is no significant difference between the difficulty of spatial visualization test and students' ability in solving spatial visualization problems in each of educational level. In a literature, Suparman and Juandi [54] stated that the instrument of test administrated to measure students' mathematical abilities had to be suitable with students' cognitive development. So, they, in each of educational level, can do and may solve the given mathematics problems which are appropriate for their ages.

3) Intervention duration

The factor of intervention duration in this current study was grouped to be three categories consisting of 1 month, 3 months, and more than 3 months. This present study finds that intervention duration was one of the significant factors causing the difference of spatial visualization of students in the geometry learning utilizing CABRI 3D software. Some relevant studies also showed that the factor of intervention duration significantly differentiated students' mathematics achievement in mathematics classroom assisted by CABRI 3D software [44, 45]. More particular, Jaya and Suparman [48] found that the gap of students' geometry achievement in CABRI 3D-assisted geometry lesson was significantly caused by intervention duration. Additionally, Hawes *et al*. [50] also revealed that intervention duration significantly influenced the difference of spatial visualization of students in the learning classroom using the intervention like as spatial training. These relevant studies justify that intervention duration significantly differentiates students' spatial visualization skills in geometry lesson assisted by CABRI 3D software.

Specifically, the implementation of CABRI 3D-assisted geometry lesson carried out during 1 month and 3 months had positive moderate effect on the enhancement of spatial visualization of students. Meanwhile, the implementation of CABRI 3D-assisted geometry learning conducted during more than 3 months had positive strong effect on the enhancement of spatial visualization of students. This implies that the effect of CABRI 3D-assisted geometry lesson performed during more than 3 months was higher than the effect of CABRI 3D-assisted geometry lesson performed during 1 month and 3 months. This indicates that the factor of intervention duration significantly generates the gap of spatial visualization skills among implementations of CABRI 3D-assisted geometry lesson carried out during 1 month, 3 months, and more than 3 months. A few of relevant studies also found that there was a different mathematics achievement among implementations of CABRI 3D-assisted mathematics learning conducted during 3 months, 6 months, and more than 6 months [43, 47]. In addition, Jaya and Suparman [48] showed that there was also a different geometry achievement among implementations of CABRI 3D-assisted geometry learning performed during 1 month, 3 months, and more than 3 months. From these relevant reports, it can be interpreted that the longer the intervention duration of geometry lesson-assisted by CABRI 3D software, the more effective it implies on the enhancement of students' spatial visualization skills.

4) Participant

The factor of participant in this recent study was categorized to be two groups consisting of Indonesian students and foreign students. This present study finds that participant did not influence the gap of spatial visualization skills of students in the geometry lesson by using this software. A meta-analysis study also showed that the factor of participant did not differentiate students' geometry achievement in CABRI 3D-assisted geometry learning [48]. This relevant study strengthens that the factor of participant is not involved in differentiating students' spatial visualization skills in geometry learning assisted by this software. Subsequently, the utilization of this software in geometry lesson had positive moderate effect on the enhancement of Indonesian and also spatial visualization of foreign students. However, the effect of CABRI 3D-assisted geometry lesson toward the enhancement of foreign students' spatial visualization skills was higher than the effect of CABRI 3D-assisted geometry lesson toward the enhancement of Indonesian students' spatial visualization skills. This was similar to Jaya and Suparman [48] finding that there was no different geometry achievement in geometry learning assisted by CABRI 3D software between Indonesian students and foreign students. From these studies, it can be said that the factor of participant, in geometry learning assisted by this software, does not generate the difference of spatial visualization between Indonesian students and foreign students.

VI. Conclusion and Implication

This present study has estimated that the utilization of CABRI 3D software in geometry lesson provides positive moderate effect toward the improvement of spatial visualization of students. Moreover, it can be justified that significantly CABRI 3D-assisted geometry lesson enhances students' spatial visualization skills. This implies that from this strong evidence, the utilization of this software for teaching geometry lesson can be an effective and even alternative way to enhance students' spatial visualization skills. Beside considering spatial visualization as one of the main spatial abilities that promotes students in solving geometry problems, especially related to three-dimensional objects, spatial visualization is also required to understand concepts and solve problems in other scientific fields, such as astronomy, chemistry, biology, physics, cartography, and geology. So, enhancing students' spatial visualization skills by implementing geometry learning has to be conducted by mathematics teachers and lecturers whereby CABRI 3D software has an important role in promoting it.

The issue regarding the gap of spatial visualization of students has been examined and investigated by this present study. It can be justified that class capacity and intervention duration are the significant factors influencing the difference of spatial visualization of students in CABRI 3D-assisted geometry learning. Meanwhile, there is no sufficient evidence to state that a few of substantial factors, such as educational level and participant differentiate students' spatial visualization in geometry classroom assisted by CABRI 3D software. From this investigation and examination on the substantial factors, it can be recommended for mathematics teachers and lecturers that the implementation of geometry lesson assisted by CABRI 3D software should be carried out in small class ($n \leq 30$ students) and during more than 3 months to get the strongest effect in enhancing students' spatial visualization skills. Thus, they, an educational practitioner in mathematics, must consider those conditions in implementing geometry lesson assisted by CABRI 3D software to help students in enhancing spatial visualization.

To conduct this present meta-analysis study, there are a few difficulties discovered by researchers. Many prospective documents identified in some electronic databases were not able to be accessed in that those documents were restricted by the publishers which published them. Consequently, they must be paid to get the access of documents. Additionally, a lot of documents which had passed through screening step were excluded in that those documents did not provide statistical data to calculate the effect size. The alternative way had been undergone to get the statistical data from each document by mailing the authors, but only a few of them gave a response and provided the complete statistical data for us. From these experiences, we suggest that for further relevant studies, researchers should directly communicate the restricted documents to authors in which asking to be provided the access to get the documents freely. Moreover, they also should set the sufficient time span to get more the statistical data from each author whereby there is a lot of efforts in finding the data tracked by using email or contact number.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Rosida Marasabessy defined research problems, decided the inclusion criteria, searched and selected documents. Yullys Helsa extracted and coded the data from each document to the coding sheet. Suparman analyzed the data and interpreted it. All authors were involved in finishing the final manuscript.

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