MODESTUM

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Fostering spatial visualization in GeoGebra-assisted geometry lesson: A systematic review and meta-analysis

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Abstract

Lots of empirical studies regarding the cultivation of spatial visualization in geometry lesson by utilizing GeoGebra software have been increasingly carried out, at least in two last decade. Of these studies, however, it can be revealed that there is a real existence of an inconsistent effect of GeoGebra-assisted geometry lesson on spatial visualization. Consequently, current study examines the overall effect of GeoGebra-assisted geometry lesson on spatial visualization, and some substantial factors that differentiate students' spatial visualization. To perform this study, a systematic review using meta-analysis was applied whereby the random effect model was selected to estimate the effect size calculated by the Hedges' equation. 33 eligible documents published in the period of 2010-2022 were included as the data in which those generated 40 units of effect size and involved 2,739 students. Several tests, such as Z, Q Cochrane, fill and trim, and funnel plot were performed to analyse the data. The results of this study revealed that the use of GeoGebra in geometry lesson had positive strong effect on spatial visualization ($g=1.070$; $p<0.001$), and significantly cultivated students' spatial visualization. Additionally, in GeoGebra-assisted geometry classroom, a few of substantial factors, such as educational level and participant significantly differentiated students' spatial visualization, whereas there was no adequate evidence to show that class capacity and intervention duration. This current study implies that mathematics lecturers or teachers can use GeoGebra as one of teaching tools in geometry lesson, and consider students' educational level and students' characteristics as participants in implementing it to cultivate spatial visualization.

Keywords: GeoGebra, geometry lesson, meta-analysis, spatial visualization, systematic review

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 (Kösa & Karakuş, 2018). Spatial visualization, in the process of mathematics learning, is applied to understanding geometry, in that it consists of visualization, rotation, and modelling (Baki et al., 2011). National Council of Teachers of Mathematics (NCTM, 2000) 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 et al. (2018), 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 (Reilly et al., 2016). A few empirical studies found that spatial visualization is an important part in understanding geometry concepts and solving geometry problems (Hartatiana et al., 2017; Muntazhimah & Miatun, 2018). Additionally, spatial visualization positively correlates to problem-solving in geometry (Aziz et al., 2020). Several studies also showed that the success of geometry achievement is the effective factor in spatial visualization skills (Kösa & Karakuş, 2010; Yenilmez & Kakmaci, 2015). This indicates that among others, those variables influence. It means that enhancing spatial visualization is going to help students

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Contribution to the literature

- The current study contributes to providing clear information about the efficiency of the geometry lesson with the help of GeoGebra in optimizing the students' spatial visualization.
- The present study contributes to providing clear information about the effectiveness of geometry lessons with the help of GeoGebra and factors such as class capacity, level of education, duration of intervention and students.

in understanding geometry concepts and also geometry problems (Kepceoğlu, 2018). In addition, they more easily understand geometric objects and relation among objects (Baratti et al., 2020).

Visualization is the main element of spatial ability and can be applied as a stimulant in the activity of geometry learning (Dere & Kalelioglu, 2020). The geometry learning recommended to enhance spatial visualization is a learning utilizing technological media (Balacheff & Kaput, 2018). Therefore, integrating computer technology in mathematics learning, particularly in geometry lessons will be important and well-known in dealing with the 21st challenging (Adelabu et al., 2019). Dynamic Geometry Software (DGS) offers some specific software, such as CABRI 3D, GeoGebra, Geometers Sketchpad, and others (ÇelİK et al., 2016). Particularly, the use of GeoGebra, one of mathematics software offering the combination between 2D and 3D DGS, computer algebra system (CAS), and spreadsheet (Santiago & Alves, 2022; Susiloningtyas et al., 2017), is one of the technological integration forms for geometry lesson. The utilization of this software enables students to have more opportunity in visualizing the concepts of geometry, which often accommodates students who have low geometry achievement (Morales Carballo et al., 2022; Nasongkhla et al., 2019). This rationality promotes the urgency to integrate GeoGebra in the geometry classroom. Moreover, Hannafin et al. (2008) stated that GeoGebra can be operated in all software which have standardized system and operated by web browser. This implies that the utilization of this software in geometry lessons can be a potentially alternative solution in cultivating students' spatial visualization, so they have extremely possible opportunities to get the high geometry achievement.

At least the last two decades, many empirical studies focusing on the cultivation of spatial visualization of students by implementing GeoGebra-assisted geometry lesson have been increasingly conducted. A lot of those studies found that the use of GeoGebra in geometry lessons significantly cultivated spatial visualization of students (Abd. Haris & Arif Rahman, 2018; Alabdulaziz et al., 2021; Erbas & Yenmez, 2011; Ersozlu et al., 2023; Fajri, 2019; Ifanda et al., 2017; Japa et al., 2017; Jelatu et al., 2018a, 2018b; Khalil et al., 2018; Kim & Md-Ali, 2017; Lv et al., 2022; Mulyo, 2021; Munawarah et al., 2021; Mushipe & Ogbonnaya, 2019; Nurmayan, 2015; Prakoso et al., 2015; Pujawan et al., 2020; Puspitasari & Junaedi, 2022; Saha et al., 2010; Singh, 2018; Siswanto & Kusumah, 2017; Sung et al., 2023; Thohirudin et al., 2016; Widada et al., 2019; Ye et al., 2023; Zengin et al., 2012a). A few other studies, however, revealed that the use of GeoGebra in geometry lesson did not have significant impact on the cultivation of spatial visualization of students (Noviana & Hadi, 2021; Yulian et al., 2020). Moreover, this software in geometry classroom provided negative effect on students' spatial visualization (Handayani et al., 2020; Sattar & Nawaz, 2017; Tomić et al., 2019; Yuliardi, 2013). These empirical studies indicate that an inconsistency of the effect of GeoGebra-assisted geometry lesson on the cultivation of students' spatial visualization is existing. Consequently, the estimation and examination on the effectiveness of this software in geometry lesson to cultivate spatial visualization must 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 in cultivating students' spatial visualization, GeoGebra-assisted geometry lesson had positive moderate effect (Alabdulaziz et al., 2021; Khalil et al., 2018; Lv et al., 2022; Singh, 2018; Sung et al., 2023; Ye et al., 2023), and even positive strong effect (Erbas & Yenmez, 2011; Ersozlu et al., 2023; Kim & Md-Ali, 2017; Mushipe & Ogbonnaya, 2019; Zengin et al., 2012b). Few studies, however, reported that on the cultivation of students' spatial visualization, GeoGebra-assisted geometry learning had positive modest effect (Tomić et al., 2019; Yulian et al., 2020), and even positive weak effect (Noviana & Hadi, 2021; Yuliardi, 2013), and worse, negative effect (Handayani et al., 2020; Tomić et al., 2019). These empirical reports show that there is a heterogeneous impact of the use of GeoGebra software in geometry lessons to cultivate spatial visualization of students. This indicates that the difference of spatial visualization of students in geometry lessons assisted by GeoGebra software is existing. Because of this issue, the investigation and examination on some substantial factors, such as class capacity, educational level, intervention duration, and participant 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 suggestions or recommendations 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.

Several previous secondary studies using a systematic review and meta-analysis focused on GeoGebra and mathematics achievement. In a meta-analysis literature, Juandi et al. (2021b) reported that of 36 empirical relevant studies collected, the effect of GeoGebra-assisted mathematics learning on students' mathematics achievement was g=0.961, whereas Kaya and Öcal (2018), of 38 eligible documents collected, revealed that the effect of GeoGebra-assisted mathematics learning on mathematics achievement of students was g=0.886. Moreover, As'ari et al. (2022), of 16 empirical studies collected, found that the effect of GeoGebra-assisted mathematics learning on mathematics achievement of students was g=0.609. All these effect sizes are categorized as moderate effect (Cohen et al., 2018). This means that the use of GeoGebra software in geometry lesson has positive moderate effect on students' mathematics achievement. A few of meta-analysis reports, however, the effect of GeoGebra-assisted mathematics learning on students' mathematics achievement was g=1.321, of five eligible documents collected (Anzani & Juandi, 2022), and g=1.201, of 14 empirical studies collected (Zhang et al., 2023), whereby all of these effect sizes are classified as strong effect (Cohen et al., 2018). It can be interpreted that the utilization of GeoGebra software in mathematics lessons has a positive effect on students' mathematics achievement. Additionally, all those meta-analysis literatures reported that the utilization of GeoGebra software in mathematics learning significantly enhanced students' mathematics achievement (Anzani & Juandi, 2022; As'ari et al., 2022; Kaya & Öcal, 2018; Zhang et al., 2023). From these relevant meta-analysis reports, it can be hypothesized that the use of GeoGebra software for teaching geometry lesson is effective in cultivating students' spatial visualization skills.

Some previously relevant meta-analysis studies also had investigated and examined the involvement of some substantial factors, such as class capacity, educational level, intervention duration, and participant. Kaya and Öcal (2018) found that educational level significantly differentiated students' mathematics achievement in GeoGebra-assisted mathematics learning while there was no adequate evidence to state that class capacity differentiates students' mathematics achievement in mathematics learning using GeoGebra software. On the other hand, Juandi et al. (2021b) revealed that class capacity and intervention duration significantly differentiated students' mathematics achievement in GeoGebra-assisted mathematics learning while there was no adequate evidence to reveal that educational level differentiates students' mathematics achievement in mathematics learning using GeoGebra software. Meanwhile, Zhang et al. (2023) showed that class capacity and intervention duration significantly differentiated students' mathematics achievement in GeoGebra-assisted mathematics learning. Of 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 difference of students' spatial visualization in GeoGebra-assisted geometry lesson.

The presentation of previously relevant studies shows that the utilization of GeoGebra software in mathematics lesson relatively has not been focused on spatial visualization skills. Consequently, this current meta-analysis study focuses on the cultivation of spatial visualization of students using GeoGebra software in teaching geometry lessons. Additionally, 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 GeoGebra-assisted geometry lesson. The purpose of this recent study is to examine the effectiveness of GeoGebra-assisted geometry lesson toward the cultivation of spatial visualization of students, and the significance of some substantial factors, such as class capacity, intervention duration, participant, and educational level in differentiating students' spatial visualization in the geometry lesson utilizing GeoGebra software. The following research questions are directed to achieve the aims of this recent study, such as:

(1) How much the effect size does GeoGebra-assisted geometry lesson have on students' spatial visualization?

(2) What does GeoGebra-assisted geometry lesson cultivate students' spatial visualization?

(3) What do some substantial factors, such as educational level, intervention duration, class capacity, or participant differentiate students' spatial visualization in geometry classroom using GeoGebra software?

THEORETICAL FRAMEWORK

Spatial Visualization

Explaining spatial visualization is inseparable from spatial ability, in that it is one of the elements of spatial ability. Kösa and Karakuş (2018) 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 (Lin & Chen, 2016; Smith & Talley, 2018). On the other hand, Sütçü (2021) explained that spatial ability is used to create visual objects stimulating our mind and manipulate these objects in the mind. Meanwhile, Güven and Kosa (2008) 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 (Sütçü, 2021). 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 (Baki et al., 2011; Güven & Kosa, 2008; Kösa & Karakuş, 2018; Smith & Talley, 2018). Meanwhile, Alansari et al. (2008) 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 (Sütçü, 2021). Indeed, spatial visualization is a main component of spatial ability, and can be applied as a strengthening stimulant to teach geometry lessons (Baki et al., 2011; Lin & Chen, 2016). A few literatures stated that spatial visualization refers to the skills in mentally manipulating, twisting, rotating, and inverting a pictorially presented stimulus (Baki et al., 2011; Kösa & Karakuş, 2018). On the other hand, Park et al. (2011) 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 (2012) argued that spatial visualization consists of manual manipulation, mental manipulation, spatial creativity, and speed of object manipulation. These elements are used to measure spatial visualization skills in each eligible document involved in this recent study.

Geometry and GeoGebra Software

Geometry is an essential part of mathematics. NCTM (2000) 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 (Kosa, 2016). Because of that, geometry concepts must be understood, and geometry problems must 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 (Dere & Kalelioglu, 2020; Juandi et al., 2021a; Kepceoğlu, 2018). Therefore, the utilization of technology, particularly computer technology in implementing geometry lessons, 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 (Kosa, 2016). 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 (Juandi et al., 2021b; Santiago & Alves, 2022). 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 GeoGebra 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 (Baki et al., 2011; Morales Carballo et al., 2022; Saralar-Aras, 2022). Particularly, Kosa (2016) stated that GeoGebra software provides an environment that makes students possible to explore geometric relationships and create and examine the geometric conjectures. Moreover, Kösa and Karakuş (2010) argued that GeoGebra 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 lessons has an important role in the improvement of spatial visualization.

Moderating Factors

The gap of students' spatial visualization skills in the learning environment filled in by GeoGebra-assisted geometry lesson indicates that there is the involvement of some moderating factors. Indirectly, these 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 factors in affecting students' heterogeneous spatial visualization. In a few literatures (e.g., Helsa et al., 2023; Tawaldi et al., 2023), stated that generally, there are two moderating factors, such as substantial and extrinsic. Moreover, Helsa et al. (2023) 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 factors are factors that do not relate to independent or dependent variables such as publication year, document

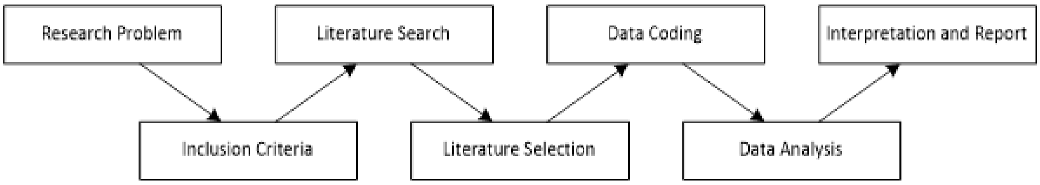

Figure 1. The steps of meta-analysis (Nugraha & Suparman, 2021)

type, source, and database. Particularly, this study focuses on the substantial factors consisting of class capacity, educational level, intervention duration, and participant to be investigated and examined in that those factors have an important role on the difference of students' spatial visualization skills.

METHOD

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 (Helsa et al., 2023; Suparman & Juandi, 2022). In a literature, Cooper et al. (2013) stated that there were seven stages in conducting a meta-analysis study (See **Figure 1**).

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. (2009), 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 GeoGebra-assisted geometry lesson,

(3) The comparator in the document was traditional geometry lesson,

(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 2010 and 2022 whereby it was indexed by Scopus and Google Scholar,

(7) The document type was article and conference paper,

(8) The document reported 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.

Document Search and Selection

Few search engines, such as: Google Scholar and ERIC were utilized to find the document. Moreover, some combinational keywords such as "spatial visualization", "GeoGebra", 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 using PRISMA (Preferred Reporting Items of Systematic review and Meta-Analysis), such as:

(1) Identification

(2) Screening

(3) Eligibility and

(4) Inclusion (Ariani et al., 2024; Tawaldi et al., 2023).

The process of document selection is presented in **Figure 2**.

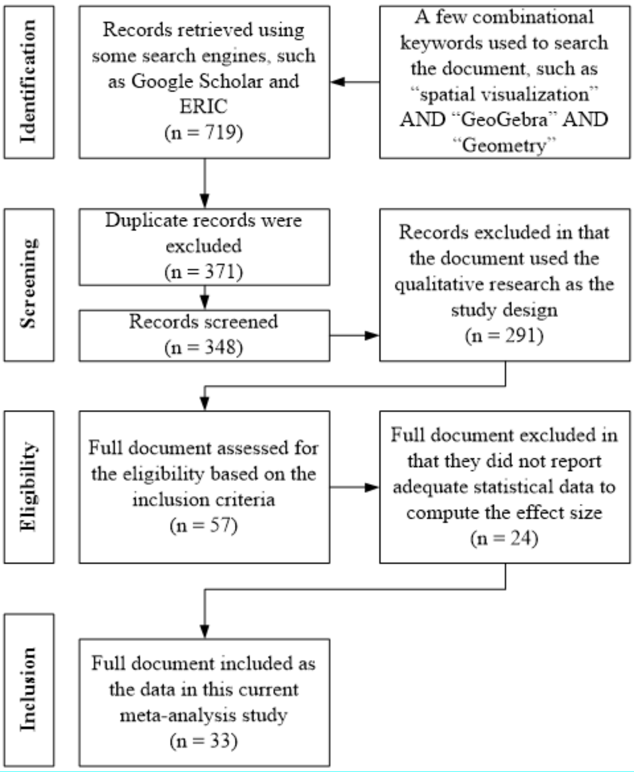

Figure 2. PRISMA flow-chart of document selection (Moher et al., 2009)

Table 1. The distribution of units of effect size based on substantial factors

Moderating Factors	Groups	Document Frequency	Percentage
Class Capacity	n ≤ 30 (Small Class)	20	50%
	n > 30 (Large Class)	20	50%
Educational Level	Elementary School	4	10%
	Middle School	18	45%
	High School	13	32%
	University/College	5	13%
Intervention Duration	1 Month	12	30%
	3 Months	4	10%
	More than 3 Months	24	60%
Participant	Indonesian Student	22	55%
	Foreign Student	18	45%

Table 2. The results of Cohen's Kappa test

Items	Kappa Value	Agreement Level	Sig.
Authors	0.932	Almost Perfect	0.005
Mean of Experiment Group	0.961	Almost Perfect	0.003
Deviation Standard of Experiment Group	0.929	Almost Perfect	0.006
Sample Size of Experiment Group	0.951	Almost Perfect	0.002
Mean of Control Group	0.966	Almost Perfect	0.002
Deviation Standard of Control Group	0.951	Almost Perfect	0.004
Sample Size of Control Group	0.936	Almost Perfect	0.005
t-value	0.921	Almost Perfect	0.006
p-value	0.971	Almost Perfect	0.001
Class Capacity	0.883	Strong	0.013
Educational Level	0.825	Strong	0.029
Intervention Duration	0.831	Strong	0.017
Participant	0.871	Strong	0.019

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 **Appendix** and **Supplementary Data**. Moreover, the categorical data were the moderating factors whereby in detail, these factors are described in **Table 1**.

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 (Fuad et al., 2023; Suparman & Juandi, 2022). To conduct it, Cohen's Kappa test was performed. McHugh (2012) stated that the measurement of Cohen's Kappa was formulated as follows:

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

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) (Cohen et al., 2018). The results of Cohen's Kappa test on statistical data and categorical data are shown in **Table 2**.

From **Table 2**, 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 (Fuad et al., 2023).

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 (Helsa et al., 2023). According to Borenstein et al. (2009), the Hedge's equation could be formulated as follows:

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

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 a 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) (Cohen et al., 2018). Furthermore, the Z test was performed to examine the significance of GeoGebra-assisted geometry lesson on students' spatial visualization skills. Additionally, the Cochran's Q test was carried out to investigate and examine the involvement of those moderating factors in differentiating students' spatial visualization skills in GeoGebra-assisted geometry lesson.

In a literature, Cooper et al. (2013) stated that the statistical data in the meta-analysis study tended to become publication bias. Publication bias was a condition in which researchers 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 (Fuad et al., 2023; Tawaldi et al., 2023). 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. (2014) also argued that the set of effect size tended to be sensitive on the change of the data quantity. Consequently, 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 4.0.

RESULTS

Publication Bias and Sensitivity Analysis

The funnel plot analysis was used to describe the distribution of effect size data in the plot (See **Figure 3**).

From **Figure 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 Helsa et al. (2023), 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.

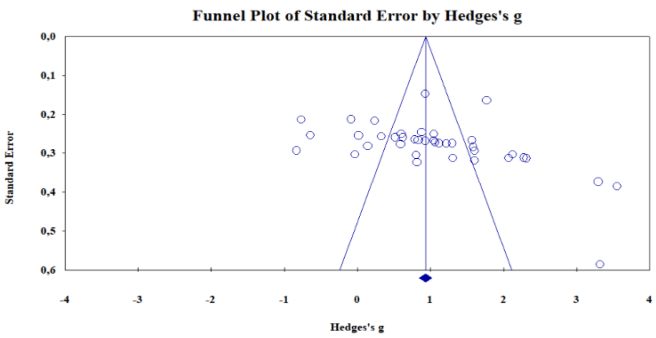

Figure 3. The results of funnel plot analysis (Source: Authors' own elaboration, using Comprehensive Meta-Analysis (CMA) Version 4.0)

Table 3. The results of fill and trim test

	Studies Trimmed	Effect Size in g Unit	Q-value
Observed Values		1.069 [0.787; 1.350]	452.792
Adjusted Values	0	1.069 [0.787; 1.350]	452.792

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 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 1.009 and the highest g unit was 1.116. Meanwhile, the average of effect size in g unit was 1.070. This means that the average effect size is in the interval between 1.009 and 1.116 whereby it indicates that the set of effect size data is not sensitive to the change of data quantity. In literature, Bernard et al. (2014) 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.

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**).

From **Table 4**, 33 valid and credible documents generated 40 effect sizes in that there were two documents resulting two effect sizes (e.g. Kim & Md-Ali,

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

Document	Effect Size in g Unit	Z-value	P-value
Siswanto and Kusumah (2017)	1.603 [1.027; 2.179]	5.455	0.000
Jelatu et al. (2018a)	1.121 [0.583; 1.659]	4.082	0.000
Mulyo (2021)	0.517 [0.009; 1.025]	1.994	0.046
Pujawan et al. (2020)	1.588 [1.031; 2.145]	5.590	0.000
Abd. Haris and Arif Rahman (2018)	1.045 [0.554; 1.536]	4.170	0.000
Ifanda et al. (2017)	3.318 [2.170; 4.467]	5.663	0.000
Japa et al. (2017)	1.299 [0.761; 1.837]	4.733	0.000
Prakoso et al. (2015)	0.786 [0.267; 1.304	2.967	0.003
Nurmayan (2015)	1.218 [0.678; 1.759]	4.416	0.000
Yuliardi (2013a)	0.143 [-0.408; 0.695]	0.509	0.611
Yuliardi (2013b)	-0.831 [-1.407; -0.256]	-2.833	0.005
Sattar and Nawaz (2017)	-0.642 [-1.139; -0.144]	-2.527	0.011
Saha et al. (2010)	0.591 [0.049; 1.133]	2.136	0.033
Noviana and Hadi (2021)	0.018 [-0.481; 0.518]	0.071	0.943
Tomić et al. (2019a)	-0.770 [-1.189; -0.352]	-3.606	0.000
Tomić et al. (2019b)	0.239 [-0.187; 0.665]	1.101	0.271
Tomić et al. (2019c)	-0.083 [-0.500; 0.334]	-0.389	0.697
Kim and Md-Ali (2017a)	3.297 [2.565; 4.029]	8.829	0.000
Kim and Md-Ali (2017b)	3.555 [2.800; 4.310]	9.232	0.000
Alabdulaziz et al. (2021)	0.835 [0.314; 1.357]	3.140	0.002
Ye et al. (2023)	0.881 [0.399; 1.363]	3.579	0.000
Yulian et al. (2020)	0.326 [-0.177; 0.829]	1.272	0.203
Khalil et al. (2018)	0.818 [0.185; 1.452]	2.532	0.011
Lv et al. (2022)	0.929 [0.641; 1.217]	6.324	0.000
Mushipe and Ogbonnaya (2019)	2.068 [1.456; 2.681]	6.618	0.000
Zengin et al. (2012b)	1.606 [0.982; 2.229]	5.043	0.000
Erbas and Yenmez (2011a)	2.125 [1.531; 2.720]	7.005	0.000
Erbas and Yenmez (2011b)	2.123 [1.529; 2.717]	7.000	0.000
Erbas and Yenmez (2011c)	2.314 [1.699; 2.928]	7.380	0.000
Erbas and Yenmez (2011d)	2.278 [1.667; 2.888]	7.311	0.000
Ersozlu et al. (2023)	1.770 [1.448; 2.092]	10.769	0.000
Thohirudin et al. (2016)	1.308 [0.695; 1.921]	4.183	0.000
Fajri (2019)	0.928 [0.401; 1.454]	3.454	0.001
Widada et al. (2019)	1.567 [1.043; 2.091	5.863	0.000
Sung et al. (2023)	0.601 [0.110; 1.092]	2.397	0.017
Munawarah et al. (2021)	1.046 [0.521; 1.570]	3.904	0.000
Handayani et al. (2020)	-0.033 [-0.627; 0.561]	-0.110	0.912
Jelatu et al. (2018b)	1.065 [0.530; 1.600]	3.904	0.000
Puspitasari & Junaedi (2022)	0.622 [0.114; 1.130]	2.398	0.016
Singh (2018)	0.802 [0.204; 1.399]	2.629	0.009
Estimated Effect Size	1.070 [0.789; 1.350]	7.466	0.000

Note. Yuliardi (2013a) and Yuliardi (2013b) represent that there are two units of effect size in one document sourced from Yuliardi (2013). Tomic et al. (2019a), Tomic et al. (2019b), and Tomic et al. (2019c) represent that there are three units of effect size in one document sourced from Tomic et al. (2019). Kim and Md-Ali (2017a) and Kim and Md-Ali (2017b) represent that there are two units of effect size in a document sourced from Kim and Md-Ali (2017).

2017; Yuliardi, 2013), followed by one document resulting three effect sizes (e.g. Tomić et al., 2019), and one document resulting four effect sizes (e.g. Erbas & Yenmez, 2011).

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 **Figure 4**.

From **Figure 4**, the data of effect size viewed by the direction consisted of 12.50% negative effect size and 87.50% positive effect size. In addition, the data of effect size viewed by the significance consisted of 15% no significant effect size and 85% significant effect size.

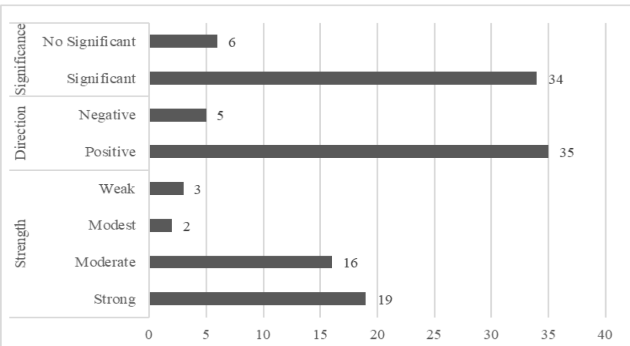

Figure 4. The frequency distribution of effect size data based on significance, strength, and direction (Source: Authors' own elaboration)

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)	0.831	2.767	1	0.096
	n > 30 (Large Class)	1.294			
Educational Level	Elementary School	2.207	66.596	3	0.000
	Middle School	1.402			
	High School	0.661			
	University/College	0.082			
Intervention Duration	1 Month	1.310	1.137	2	0.566
	3 Months	1.126			
	More than 3 Months	0.947			
Participant	Indonesian Student	0.806	3.948	1	0.047
	Foreign Student	1.385			

Meanwhile, the data of effect size viewed by the strength contained in 7.50% weak effect size, 5% moderate effect size, 40% modest effect size, and 47.50% strong effect size. These show that the data of effect size is dominated by significant, positive, and moderate effect size. **Figure 4** also shows that the estimated effect size was 1.070 whereby it interprets that GeoGebra-assisted geometry lesson has positively strong 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 GeoGebra software in geometry lessons significantly cultivates students' spatial visualization skills. In another interpretation, it indicates that GeoGebra-assisted geometry lesson is effective in cultivating students' spatial visualization skills.

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 differentiating spatial visualization of students in the geometry learning utilizing GeoGebra software.

From **Table 5**, the estimated significance value of the Q Cochrane test for a few factors, such as educational level and participant was less than 0.05. This interprets that educational level and participant significantly differentiate spatial visualization of students in GeoGebra-assisted geometry lesson. Meanwhile, the estimated significance value of the Q Cochrane test for some substantial factors, such as class capacity and intervention duration were more than 0.05. This interprets that class capacity and intervention duration are not the factors affecting the difference of spatial visualization of students in the geometry lesson using GeoGebra software.

DISCUSSION

The Effect of the Utilization of GeoGebra Software in Geometry Lesson on Students' Spatial Visualization Skill

The present study reveals that the geometry lesson utilizing GeoGebra software had a positive strong effect on the cultivation of spatial visualization of students. This is like some relevant studies reporting that GeoGebra-assisted mathematics learning also had a positive strong effect toward the cultivation of students' mathematics achievement (Anzani & Juandi, 2022; Zhang et al., 2023). These relevant studies provide strong evidence that GeoGebra-assisted geometry lessons have a positive effect on spatial visualization of students. Moreover, the current study also shows that GeoGebra-assisted geometry lesson significantly affected the cultivation of spatial visualization of students. It interprets that the utilization of GeoGebra software for teaching geometry lessons is effective in cultivating students' spatial visualization skills. Several previously relevant studies also revealed that the intervention of mathematics learning assisted by GeoGebra software significantly enhanced students' mathematics achievement (Anzani & Juandi, 2022; As'ari et al., 2022; Kaya & Öcal, 2018; Zhang et al., 2023). Those relevant reports strengthen the findings of this recent study that GeoGebra-assisted geometry lesson is one of the effectively alternative interventions in cultivating spatial visualization of students.

Since the 1990s, GeoGebra software as one of the DGS, beside CABRI 3D, Geometers' Sketchpad and Cinderella, has been widely utilized for teaching geometry lessons. 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 cultivation of spatial visualization skills on students by implementing the geometry lesson. In a literature, Kösa and Karakuş (2018) stated that spatial visualization is one of the main indicators of spatial ability, besides spatial perception, spatial orientation, mental rotation, and spatial relation.

Spatial visualization had by students can promote them in understanding geometry concepts and solving geometry problems (Nurjanah et al., 2020). 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 (Kusar, 2012; Sütçü, 2021). Consequently, the existence and development of GeoGebra software is extremely needed to improve spatial visualization of students.

The intervention of geometry lessons by utilizing GeoGebra enables students to explore the components of 3D objects, such as plane, angle, and distance, in real situations. This is because this software presents an environment whereby, they can investigate geometric relationships and create and examine the conjectures (Kösa & Karakuş, 2018). Moreover, Baki et al. (2011) argued that the unique feature of GeoGebra 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 (Karakuş & Peker, 2015; Kosa, 2016). 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 (Cantürk Günhan & Açan, 2016; Hwajin & Kwangho, 2021). It can be said that the features on this software offer extraordinary opportunities for students to enhance their spatial visualization skills. Therefore, GeoGebra-assisted geometry lessons can effectively cultivate students' spatial visualization skills.

The Difference of Students' Spatial Visualization Skills in GeoGebra-assisted Geometry Lesson

The difference of students' spatial visualization skills in geometry lesson utilizing GeoGebra 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 substantial factors, such as educational level and participation were significant factors in affecting the difference of students' spatial visualization skills in the geometry lesson by using GeoGebra software. Meanwhile, other substantial factors, such as intervention duration and class capacity were not the potential factors in affecting students' heterogeneous spatial visualization skills in GeoGebra-assisted geometry lesson. Each of substantial factor is discussed and explained in the following subsection.

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 not the significant factor affecting the difference of students' spatial visualization skills in the geometry lesson utilizing GeoGebra software. This was similar to one relevant study showing that the factor of class capacity did not differentiate students' mathematics achievement in mathematics classroom assisted by GeoGebra software (Kaya & Öcal, 2018). This relevant report justifies that there is no adequate evidence to state that class capacity differentiates spatial visualization of students in geometry classroom using GeoGebra software. In detail, the utilization of GeoGebra software in geometry lesson had positive moderate effect on the cultivation of spatial visualization of students in small class, whereas the utilization of GeoGebra software in geometry lesson had positive strong effect on the cultivation of spatial visualization of students in small class. Consequently, the effect of GeoGebra-assisted geometry lesson in small class was lower than the effect of GeoGebra-assisted geometry lesson in large class. This indicates that the factor of class capacity, in GeoGebra-assisted geometry lesson, descriptively creates the difference of spatial visualization skills between students who learn in small class and students who learn in large class. A relevant study also showed that there was a different mathematics achievement in mathematics classroom utilizing GeoGebra software among students who study in small class and large class (Kaya & Öcal, 2018). From these reports, it can be interpreted that mathematics teachers who teach geometry material by utilizing GeoGebra software in large class have more opportunities like as a time than they teach geometry lesson by using this software in small class.

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 significantly influenced the difference of spatial visualization of students in the geometry lesson by using GeoGebra software. A relevant study also showed that educational level differentiated students' mathematics achievement in GeoGebra-assisted geometry lesson (Kaya & Öcal, 2018). This relevant study provides strong evidence that this factor has the involvement in differentiating students' spatial visualization skills in geometry lesson assisted by this software. Particularly, the implementation of geometry lesson assisted by GeoGebra software had positive strong effect on spatial visualization of students in elementary and middle school. Meanwhile, geometry classroom promoted by this software had positive moderate effect on high school students' spatial visualization, and even positive weak effect on college/university students' spatial visualization. This interprets that the effect of GeoGebra-assisted geometry lesson for cultivating students' spatial visualization skills in elementary school is higher than the effect of GeoGebra-assisted geometry lesson for cultivating middle & high school, and university/college students' spatial visualization skills. It means that the utilization of this software to teach geometry lessons is more effective in cultivating students' spatial visualization in elementary school than middle & high school, and university/college students' spatial visualization. Moreover, the factor of educational level was involved in affecting the difference 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. Consequently, there is a significant difference between the difficulty of spatial visualization test and students' ability in solving spatial visualization problems in each educational level. In literature, Helsa et al. (2023) 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.

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 not the significant factor causing the difference of spatial visualization of students in the geometry lesson utilizing GeoGebra software. A few of relevant studies also showed that the factor of intervention duration did not differentiate students' mathematics achievement in mathematics classroom assisted by GeoGebra software (Zhang et al., 2023). These relevant studies justify that there is no adequate evidence to reveal that intervention duration differentiates students' spatial visualization skills in geometry lessons assisted by GeoGebra software. Specifically, the implementation of GeoGebra-assisted geometry lesson carried out for 1 month and 3 months had a positive strong effect on the cultivation of spatial visualization of students. Meanwhile, the implementation of GeoGebra-assisted geometry lesson conducted over more than 3 months had positive moderate effect on the cultivation of spatial visualization of students. This implies that the effect of GeoGebra-assisted geometry lesson performed for 1 month was higher than the effect of GeoGebra-assisted geometry lesson performed for 3 months and more than 3 months. This indicates that the factor of intervention duration descriptively generates the difference of spatial visualization skills among implementations of GeoGebra-assisted geometry lesson carried out for 1 month, 3 months, and more than 3 months. A few relevant studies also found that there was a descriptively different mathematics achievement among implementations of GeoGebra-assisted mathematics learning conducted for 3 months, 6 months, and more than 6 months (Zhang et al., 2023). From these relevant reports, it can be interpreted that the longer the intervention duration of geometry lesson-assisted by GeoGebra software, the less effective it implies on the cultivation of students' spatial visualization skills.

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 participants significantly influenced the difference of spatial visualization skills of students in the geometry lesson by using GeoGebra software. A relevant meta-analysis study also showed that the factor of participant differentiated students' geometry achievement in DGS-assisted geometry lesson (Yulian et al., 2020). This relevant study strengthens that the factor of participant is involved in differentiating students' spatial visualization skills in geometry lesson assisted by GeoGebra software. Subsequently, the utilization of GeoGebra software in geometry lesson had positive moderate effect on the cultivation of Indonesian and positive strong effect on spatial visualization of foreign students. Consequently, the effect GeoGebra-assisted geometry lesson toward the cultivation of foreign students' spatial visualization skills was higher than the effect of GeoGebra-assisted geometry lesson toward the cultivation of Indonesian students' spatial visualization skills. This was similar to Ariani et al. (2024) finding that there was different geometry achievement in geometry lesson assisted by DGS between Indonesian students and foreign students. From these reports, it can be said that the factor of participant, in geometry lesson assisted by GeoGebra software, generates the difference of spatial visualization between Indonesian students and foreign students.

CONCLUSION, IMPLICATION, AND LIMITATION & SUGGESTION

Conclusion and Implication

This present study has estimated that the utilization of GeoGebra software in geometry lesson provides positive strong effect toward the cultivation of spatial visualization of students. Moreover, it can be justified that significantly GeoGebra-assisted geometry lesson cultivates students' spatial visualization skills. This implies that from this strong evidence, the utilization of this software for teaching geometry lessons can be an effective and even alternative way to cultivate 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, cultivating students' spatial visualization skills by implementing geometry learning must be conducted by mathematics teachers and lecturers whereby GeoGebra software has an important role in promoting it.

The issue regarding the difference of spatial visualization of students has been examined and investigated by this present study. It can be justified that educational level and participation are the significant factors influencing the difference of spatial visualization of students in GeoGebra-assisted geometry lessons. Meanwhile, there is no sufficient evidence to state that a few of substantial factors, such as class capacity and intervention duration differentiate students' spatial visualization in geometry classroom assisted by GeoGebra 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 GeoGebra software should be carried out in elementary school and for 1 month to get the strongest effect in cultivating students' spatial visualization skills. Thus, they, an educational practitioner in mathematics, must consider those conditions in implementing geometry lesson assisted GeoGebra software to help students in cultivating spatial visualization.

Limitation and Suggestion

To conduct this present meta-analysis study, there were 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 access to 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 a 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.

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APPENDIX - Data coding

Code	Authors	Statistical Data								Class Capacity	Educational Level	Participant	Intervention Duration
		Intervention			Comparator			t-value	p-value				
		Mean	SD	N	Mean	SD	N						
A1	Siswanto and Kusumah (2017)	16.3	1.6	30	13.43	1.92	30			Small Class (n<=30)	Middle School	Indonesian Student	More than 3 Months
A2	Jelatu et al. (2019)	76.333	11.885	30	61.416	14.273	30			Small Class (n<=30)	Middle School	Indonesian Student	More than 3 Months
A3	Mulyo (2021)	64.27	17.763	30	54.93	17.917	30			Small Class (n<=30)	High School	Indonesian Student	More than 3 Months
A4	Pujawan et al. (2020)	15.281	1.49	32	12.66	1.76	32			Large Class (n > 30)	Middle School	Indonesian Student	More than 3 Months
A5	Haris and Rahman (2018)	86.52	7.21	36	77.86	9.1	35			Large Class (n > 30)	University College	Indonesian Student	More than 3 Months
A6	Ifanda et al. (2017)	64.31	16.368	13	22.14	6.689	14			Small Class (n<=30)	Middle School	Indonesian Student	1 Month
A7	Japa et al. (2017)	86.72	6.51	32	78.04	6.69	31			Large Class (n > 30)	Middle School	Indonesian Student	More than 3 Months
A8	Prakoso et al. (2015)	79.37	12.05	30	67.83	16.59	30			Small Class (n<=30)	Middle School	Indonesian Student	More than 3 Months
A9	Nurmayan (2015)	31.52	6.41	31	24.3	5.21	30			Large Class (n > 30)	Middle School	Indonesian Student	1 Month
A10	Yuliardi (2013a)	16.33	2.239	24	16.04	1.719	25			Small Class (n<=30)	High School	Indonesian Student	More than 3 Months
A10	Yuliardi (2013b)	14.25	2.467	24	16.04	1.719	25			Small Class (n<=30)	High School	Indonesian Student	More than 3 Months
A11	Nurdiansyah (2017)	63.44	14.16	34	73.33	16.36	30			Large Class (n > 30)	Middle School	Indonesian Student	More than 3 Months
A12	Saha et al. (2010)	65.23	19.202	27	54.7	15.66	26			Small Class (n<=30)	High School	Foreign Student	More than 3 Months
A13	Noviana and Hadi (2020)	9.67	2.5	30	9.63	1.81	30			Small Class (n<=30)	University College	Indonesian Student	More than 3 Months
A14	Tomic et al. (2019a)	43.2	14.74	49	52.68	8.53	44			Large Class (n > 30)	University College	Foreign Student	1 Month
A14	Tomic et al. (2019b)	55.93	11.42	40	53.36	9.89	44			Large Class (n > 30)	University College	Foreign Student	1 Month
A14	Tomic et al. (2019c)	30.54	5.07	42	31	5.89	45			Large Class (n > 30)	University College	Foreign Student	1 Month
A15	Kim and Md-Ali (2017a)	14.5	2.4	33	7.08	2.04	34			Large Class (n > 30)	Middle School	Foreign Student	More than 3 Months
A15	Kim and Md-Ali (2017b)	14.36	2.01	35	7.08	2.04	34			Large Class (n > 30)	Middle School	Foreign Student	More than 3 Months
A16	Alabdulaziz et al. (2020)	7.6	2.71	30	5.367	2.566	30			Small Class (n<=30)	Middle School	Foreign Student	3 Months
A17	Bakar et al. (2015)	18.31	7.34	35	12.22	6.31	36			Large Class (n > 30)	Middle School	Foreign Student	1 Month
A18	Yulian et al. (2020)	79.1	8.28	30	76.27	8.83	30			Small Class (n<=30)	High School	Indonesian Student	More than 3 Months
A19	Khalil et al. (2018)	70	13.5	20	56.95	17.5	20			Small Class (n<=30)	High School	Foreign Student	3 Months
A20	Reis and Ozdemir (2010)	5.89	1.768	102	4.14	1.98	102			Large Class (n > 30)	High School	Foreign Student	More than 3 Months
A21	Mushipe and Ogbonnaya (2019)	51.76	17.95	33	20	11.161	29			Small Class (n<=30)	Middle School	Foreign Student	More than 3 Months
A22	Zengin et al. (2011)	72.39	12.51	25	54.09	9.83	26			Small Class (n<=30)	High School	Foreign Student	3 Months
A23	Erbas and Yenmez (2011a)	69.29	13.26	33	45.78	8.06	34			Large Class (n > 30)	Elementary School	Foreign Student	1 Month
A23	Erbas and Yenmez (2011b)	69.29	13.26	33	43.81	10.33	34			Large Class (n > 30)	Elementary School	Foreign Student	1 Month
A23	Erbas and Yenmez (2011c)	69.11	11.61	33	45.78	8.06	34			Large Class (n > 30)	Elementary School	Foreign Student	1 Month
A23	Erbas and Yenmez (2011d)	69.11	11.61	33	43.81	10.33	34			Large Class >30)	Elementary School	Foreign Student	1 Month
A24	Philip et al. (2011)	53.09	10.13	105	32.62	12.82	100			Large Class (n > 30)	Middle School	Foreign Student	1 Month
A25	Thohirudin et al. (2017)	52.1	13.03	20	38.9	7.21	30			Small Class n<=30)	High School	Indonesian Student	3 Months
A26	Fajri (2016)			30			30	3.643		Small Class (n<=30)	Middle School	Indonesian Student	More than 3 Months
A27	Widada et al. (2019)			36			36	6.723		Large Class (n > 30)	High School	Indonesian Student	More than 3 Months
A28	Yuliardi and Casnan (2017)			33			32		0.017	Large Class (n > 30)	High School	Indonesian Student	More than 3 Months
A29	Rahman and Saputra (2022)			31			31		0.0001	Large Class (n > 30)	High School	Indonesian Student	More than 3 Months
A30	Handayani et al. (2020)			20			22		0.913	Small Class (n<=30)	High School	Indonesian Student	More than 3 Months
A31	Jelatu et al. (2018)			30			30		0.0001	Small Class n<=30)	Middle School	Indonesian Student	More than 3 Months
A32	Puspitasari et al. (2022)			29			32		0.017	Small Class (n<=30)	Middle School	Indonesian Student	More than 3 Months
A33	Singh (2018)			22			23		0.009	Small Class (n<=30)	Middle School	Foreign Student	1 Month