ICT-Based or -Assisted Mathematics Learning and Numerical Literacy: A Systematic Review and Meta-Analysis

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***Abstract*—Numerous empirical studies related to the use of Information and Communication Technology (ICT) in mathematics learning for enhancing numerical literacy have been increasingly carried out in three last decades. Of those studies, however, it can be stated that ICT-based or -assisted mathematics learning has an inconsistent effect on numerical literacy. Consequently, this recent study aims to examine the effectiveness of ICT-based or -assisted mathematics learning on numerical literacy skills, and several substantial factors in differentiating students' numerical literacy. A systematic review combined to meta-analysis was performed to carry out this study whereby 53 documents published in the period of 2001–2023 were involved as the data. Overall, those documents generated 64 units of effect size and 6,599 students. Some tests, such as Z, Q Cochrane, fill & trim, and funnel plot were used to analyze the data. The results of this current study reported that ICT-based or -assisted mathematics learning had positive moderate effect (g = 0.527; p < 0.05) on students' numerical literacy, and significantly enhanced students' numerical literacy. Additionally, educational level, learning environment, intervention duration, and instrument type were significant factors in differentiating students' numerical literacy. Meanwhile, there was no sufficient evidence to state that other substantial factors, such class capacity, participant, technology used, mathematical content, and technology role significantly affected students' heterogeneous numerical literacy. This study suggests mathematics educator, such as teacher and lecturer to integrate ICT in mathematics learning, especially in enhancing numerical literacy. Moreover, they have to consider some factors, such as educational level, learning environment, intervention duration, and instrument type in performing ICT-based or -assisted mathematics lesson, mainly in cultivating students' numerical literacy.**

***Keywords*—Information and Communication Technology (ICT), mathematics learning, meta-analysis, numerical literacy, systematic review**

I. INTRODUCTION

Numerical literacy, one of six basic literacies mentioned by the World Economic Forum in 2015 [1], becomes an essential for students in understanding mathematics. It refers to an ability and the knowledge to use various kinds of symbols and numbers regarding basic mathematics in solving daily life problems in multiple contexts, analyze the information presented in some forms, such as table, graph, and diagram and provide interpretations related to those, and create decisions based on analysis and interpretation [2–4]. Additionally, it is a skill used to convert objects into symbols, organize the data, and decide the right formula to measure a certain object [5–8]. Knowledge regarding number of operations, sequences, and symbols is extremely required for students as a basis for carrying out mathematical operations. Consequently, numerical literacy is so essential in that it is a basic ability in calculating and interpreting real objects appearing usually in daily life. Moreover, it can be an important skill for students in undergoing their careers in a variety of scientific disciplines in the future [8]. This implicates that it must be cultivated on students from now on in which it can be realized by training them like as finding the information using numbers around the school environment. In addition, letting in Information and Communication Technology (ICT) into mathematics learning also can help students to create it more real in that ICT can promote in visualizing real objects to be symbols, organizing the data, and calculating a certain object using the right formula.

In the 21st-century, the fast advance of technology has an important role in lots of educational fields, especially in mathematics education. The existence of technology in mathematics learning promotes teachers in presenting and explaining mathematical contents, such as algebra, geometry, number and operations, measurement, and others [9–13]. Moreover, it makes students easier in understanding mathematics concepts and solving mathematics problems [14]. This indicates that ICT plays a fundamental role in the activities of mathematics learning. Generally, the role of technology in mathematics education consists of two main functions, such as technology-based learning and technology-assisted learning [15–17]. Particularly, Gamit [15] explained that ICT-based mathematics learning refers to the utilization of technology whereby it is fully used during the process of mathematics learning implemented. For this case, some online learning platforms applied for distance learning, such as Google classroom, Edmodo, Moodle, Zoom and others can be examples of ICT-based mathematics learning [18, 19]. Meanwhile, ICT-assisted mathematics learning refers to the use of technology which only utilized in some of the process parts in mathematics learning activities [16]. For example, the involvement of Dynamic Geometry Software (DGS) and Computer Algebra System (CAS) in mathematics learning activities [20, 21]. Therefore, the utilization of ICT-based or-assisted mathematics learning can enable in promoting the enhancement of students' numerical literacy.

At least in two last decades, a lot of empirical studies which focus on the use of ICT-based or -assisted mathematics learning for cultivating numerical literacy have been carried out widely in numerous educational institutions around the world. Some studies revealed that ICT-based or -assisted mathematics learning had significant positive effect on students' numerical literacy [22–38]. Nevertheless, some

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other studies showed that ICT-based or -assisted mathematics learning did not have significant effect on students' numerical literacy [39–49]. Moreover, several studies found that ICT-based or -assisted mathematics learning had significant negative effect on students' numerical literacy [50–60]. Of these reports, it can be stated that ICT-based or -assisted mathematics learning has an inconsistent effect on the enhancement of students' numerical literacy skills, whereas clear and precise information regarding the consistency of the effectiveness of ICT use in mathematics learning for numerical literacy is required.

In another case, many studies showed that ICT-based or -assisted mathematics learning had moderate positive effect on students' numerical literacy [23, 25, 29, 33, 37, 39, 61–66]. Even, other numerous studies revealed that ICT-based or -assisted mathematics learning had strong positive effect on students' numerical literacy [24, 26, 27, 30, 32, 34–36, 38, 52, 67–72]. Meanwhile, some studies showed that ICT-based or -assisted mathematics learning had modest positive effect on students' numerical literacy [22, 28, 31, 40–42, 45, 47]. Moreover, a few of studies revealed that ICT-based or -assisted mathematics learning had weak positive effect on students' numerical literacy [43, 44, 46, 48, 49, 73]. Of these reports, it can be stated that there is heterogeneous effect of ICT-based or -assisted mathematics learning on students' numerical literacy. This shows that there is a gap of students' numerical literacy in mathematics learning utilizing ICT. Consequently, the investigation on some substantial factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology that have a potential role in differentiating students' numerical literacy in ICT-based or -assisted mathematics learning must be carried out comprehensively.

Previously relevant meta-analysis studies show that generally, the use of ICT in mathematics learning activities focuses on the enhancement of students' mathematics achievement, specifically in geometry and algebra lesson. However, it has not been utilized for cultivating students' numerical literacy. Consequently, this recent meta-analysis study focuses on the cultivation of students' numerical literacy in ICT-based or -assisted mathematics learning. Additionally, this current study focuses on the investigation of several substantial factors differentiating students' numerical literacy. Therefore, the purpose of this current study is to examine the effectiveness of ICT-based or -assisted mathematics learning in cultivating students' numerical literacy, and the significance of some substantial factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology in making different students' numerical literacy in mathematics learning activities utilizing ICT. This recent study contributes in providing the rigorous and strong evidences that the use of ICT in mathematics learning is one of the effective ways to enhance students' numerical literacy. Moreover, this study also provides the policy suggestions for mathematics educators related to some factors, such as educational level, learning environment, intervention duration, and instrument type in performing ICT-based or -assisted mathematics lesson, mainly in cultivating students' numerical literacy. The following research questions are directed to specify the aim of this current study:

1) How much effect does ICT-based or -assisted mathematics learning have on students' numerical literacy? Moreover, does ICT-based or -assisted mathematics learning significantly enhance students' numerical literacy?
2) Do some potential factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology significantly differentiate students' numerical literacy in mathematics learning using ICT?

II. Literature Review

A. *ICT and Mathematics Learning*

ICT is defined as a tool used to handle the information and analyze the information (communication way) with the computer assistance in converting, changing, saving, analyzing, sharing, and receiving the information [74, 75]. Moreover, Gamit [15] stated that ICT is utilized to analyze, process, get, set, and manipulate the data in various ways that it can generate the qualified information, a relevant, accurate, and precise information. The information is used as individual or group needs, such as business, government, organization, education, and others to create strategic steps and take decisions. In a literature, Rodriguez-Jimenez *et al*. [14] mentioned that ICT contains three elements, such as computer (computer system), communication, and operating skills. The benefit of ICT appearance will be increasingly felt if individuals have competences to know what, when, and how ICT can be used optimally.

Mathematics becomes the main subject taught in every educational level. This is proposed to provide students related to skills or abilities, such as numerical literacy, conceptual understanding, reasoning, communication, connection, logic, critical, and creative thinking, and problem-solving [76]. As a consequence, students can use these skills to solve daily life problems. This implicates that the qualified mathematics learning has to be provided for students that they can get and mastery these abilities. Moreover, Kortesi *et al*. [77] stated that mathematics learning refers to teachers' effort for students to get the mathematics concepts in a variety of contents, such as number and operations, algebra, measurement, geometry, and statistics & probability that they can accurately and precisely apply those in solving daily life problems. So, whatever promoting factors that can facilitate the activities of mathematics learning have to be involved in the learning environment.

ICT has a fundamental role in educational field, especially in mathematics learning. A lot of mathematical contents require the support of ICT when those contents are presented and explained to students. This implicates that mathematics teachers have to adequately technological, pedagogical, and content knowledge while students at least must have technological and content knowledge. Ran *et al*. [78] stated that knowledge and understanding of teacher and student in using technologies are an important factor in cultivating and enhancing students' knowledge in mathematics. Moreover, ICT can generate innovative and creative learning media in which it can construct an interesting mathematics learning environment. Generally, the utilization of ICT in mathematics learning can be categorized to be three functions, such as interactive Compact Disk (CD), learning tools like as mathematics software, and learning resources involving the internet like as online platforms [79, 80]. Some mathematics software, such as DGS and CAS can facilitate teachers in presenting and explaining mathematical contents and make easy students in understanding mathematics concepts and solving mathematics problems [81, 82]. Additionally, several online platforms, such as Zoom, Google classroom, Moodle, Edmodo, and others can facilitate the activities of distancing mathematics learning [13, 83]. Therefore, there are lots of real contribution of ICT in educational field, mainly in mathematics education.

B. Numerical Literacy

Numerical literacy, a basic skill in mathematics, refers to an ability to use numbers and symbols in mathematics to solve daily life problems and analyze the presented information for taking decisions [5, 6]. Moreover, Kljajevic [2] stated that numerical literacy is defined as an ability to analyze the numbers and data, and also evaluate some statements involving mental and thinking that are suitable to problem and reality. Of these explanations, it can be stated that numerical literacy is an ability to apply number concepts and operation skills in daily life in home, work, and participation in society, and interpret quantitative information that is all around us. Additionally, some literatures state that if students have had numerical literacy skills, they can cultivate their skills in using a variety of numbers and symbols related to basic mathematics to solve various daily contextual problems, analyzing the presented information in various forms, such as graph, table, chart, and others, and interpreting analysis results to make predictions and decisions [2, 5, 6]. In general context, numerical literacy skills can increase the quality of human resources and standard of human life. The point of view is that it is useful for students in handling and solving daily problems in their life.

C. Relevant Secondary Studies

A lot of previous secondary studies combining between systematic review and meta-analysis related to ICT-based or -assisted mathematics learning and mathematics academic achievement have been conducted massively. Some meta-analysis studies found that computer technology -assisted mathematics education had significant positive effect in enhancing students' mathematics achievement [9, 10, 13, 84–88]. Particularly, other few meta-analysis studies revealed that the utilization of mathematics software also had significant positive effect on students' mathematics learning outcomes [82, 89–91]. More specific, a few meta-analysis studies showed that the use of mathematics software, such as DGS and CAS had significant positive effect in cultivating students' geometric and algebraic achievement [92–95]. In case of DGS, some meta-analysis studies reported that a few specific geometry software, such as CABRI 3D and GeoGebra also had significant effect on students' geometry and algebra learning outcomes [11, 96–101]. All of those meta-analysis reports conclude that ICT-based or -assisted mathematics learning is effective in enhancing or cultivating students' mathematics achievement. Consequently, it can be hypothesized that ICT-based or -assisted mathematics learning significantly enhances students' numerical literacy.

D. Substantial Factor

The discrepancy of students' numerical literacy in ICT-based or -assisted mathematics learning indicates that the involvement of some moderating factors is exactly exist in which indirectly, these factors differentiate students' numerical literacy. This condition interprets that some students have low numerical literacy whereas some other students have high numerical literacy, and even, many students have moderate numerical literacy. As a consequence, it is extremely important to examine the significance of these factors in differentiating students' numerical literacy. Generally, Suparman and Juandi [102] stated that moderating factor consists of substantial factor and extrinsic factor. Particularly, substantial factor refers to the factors which are directly related to independent or dependent variable, such as educational level, participant, intervention duration, class capacity, and others while extrinsic factor refers to the factors is not related to independent or dependent variable, such as publication year, document type, source, and database [10]. This current study will examine some substantial factors predicted in differentiating students' numerical literacy in ICT-based or -assisted mathematics learning.

Numerous meta-analysis studies regarding ICT-based or -assisted mathematics learning and mathematics achievement examined the involvement of several substantial factors, such as educational level [9, 10, 84, 85], instrument [13, 86–88], participant [82, 89, 91, 103], intervention duration [92–94, 104], class capacity [11, 96, 97], mathematical content [98–100, 105], and school geographical location [10, 106]. Moreover, some meta-analysis studies found that those factors, such as class capacity, educational level, intervention duration, participant, mathematical content, instrument, and school geographical location significantly differentiated students' mathematics achievement in ICT-based or -assisted mathematics learning [9–11, 86, 88, 91, 93, 94, 97, 100, 101]. Several meta-analysis studies, however, revealed that there was no sufficient evidence to state that these factors, such as class capacity, educational level, intervention duration, participant, mathematical content, instrument, and school geographical location significantly differentiated students' mathematics learning outcome in mathematics learning activities utilizing ICT [13, 82, 84, 85, 87, 89, 90, 92, 95, 96, 98, 99, 106]. Of those reports, it can be hypothesized that several factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology have a potential role in differentiating students' numerical literacy in ICT-based or -assisted mathematics learning.

III. Methods

A. Research Design

A systematic review combined to meta-analysis was performed to carry out this current study. Random effect model was chosen as an estimated model in that all of empirical studies embroiled as the data had the heterogeneity in some characteristics, such as instrument, intervention duration, class capacity, school geographical location, educational level, participant, and others [102, 107]. In a book chapter, Cooper *et al.* [108] stated that there were seven steps to perform meta-analysis, such as: (1) research problem, (2) inclusion criteria, (3) document search, (4) document selection, (5) data coding, (6) data analysis, and (7) interpretation and report.

B. Inclusion Criteria

To limit the research problems formulated in this current meta-analysis, some inclusion criteria were decided in which the Population, Intervention, Comparator, Outcome, & Study Design (PICOS) approach initiated by Moher *et al*. [109], was applied to do it. The inclusion criteria were such as: (1) the document was published in the period of 2001–2023 in which it was journal article indexed by Google Scholar or Scopus; (2) the document provided the adequate statistical data to compute the effect size; (3) the study design in the document was quasi-experiment research using post-test only control group; (4) the intervention in the document was various mathematics learning environments utilizing ICT; (5) the population in the document was Asian, African, American, European, or Australian students in a variety of educational levels from primary school to college/university; (6) the outcome in the document was numerical literacy; and (7) the comparator in the document was mathematics learning activities that are not promoted by ICT. This implicated that 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

Some search engines, such as Science Direct, ERIC, Taylor & Francis Online, Semantic Scholar, and Google Scholar were used to find the document. Additionally, a few combinational keywords, such as “ICT-based mathematics learning” or “ICT-assisted mathematics learning” and “numerical literacy” were typed in those search engines to simplify the document search. Several resources stated that there were four steps to select the document systematically, such as: (1) identification, (2) screening, (3) eligibility, and (4) inclusion [12, 110–115]. The process of document selection is presented in Fig. 1.

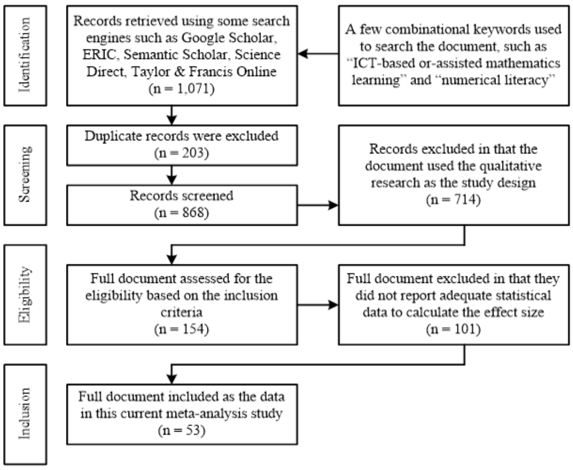

Fig. 1. PRISMA flow-chart of document selection of this meta-analysis study.

D. Data Coding

To facilitate in the process of data coding, the coding sheet was used as the instrument whereby some information, such as statistical data, categorical data, and supplementary data were extracted from each document to the coding sheet. Specifically, the statistical data consisted of sample size, mean, standard deviation, *p*-value, and *t*-value while the categorical data consisted of class capacity, educational level, intervention duration, participant, learning environment, technology used, mathematical content, instrument type, and the role of technology. Additionally, the supplementary data were such as author, publication year, document type, indexer, search engine, email, and URL. Furthermore, the information regarding the categorical data became substantial factors that would be examined in this recent study in which in detail, these factors are specified in Table 1.

Table 1. The distribution of documents based on substantial factors

Substantial Factors	Groups	Frequency in Effect Size Unit	Percentage (%)
Class Capacity	$n \leq 30$ (Small Class)	27	42.19
	$n > 30$ (Large Class)	37	57.81
Educational Level	Primary School	26	40.62
	Secondary School	35	54.69
	College/University	3	4.69
Participant	African Students	7	10.94
	American Students	10	15.62
	Asian Students	43	67.19
	Australian Students	1	1.56
	European Students	3	4.69
Intervention Duration	1–4 Weeks	9	14.06
	5–8 Weeks	10	15.62
	9–12 Weeks	7	10.94
	13–16 Weeks	9	14.06
	17–20 Weeks	4	6.25
	21–24 Weeks	8	12.50
	25–48 Weeks	11	17.19
	49–96 Weeks	6	9.37
Learning Environment	Blended Learning	5	7.81
	Computer-based Learning	5	7.81
	Cooperative Learning (STAD)	4	6.25
	Cooperative Learning (Jigsaw)	6	9.37
	Cooperative Learning (NHT)	5	7.81
	Cooperative Learning (TSTS)	7	10.94
	Direct Learning	7	10.94
	Discovery Learning	9	14.06
	Game-based Learning	4	6.25
	Inquiry-based Learning	3	4.69
	Problem-based Learning	6	9.37
	Project-based Learning	3	4.69
Technology Used	Adobe Flash	2	3.12
	Animation Video	8	12.50
	CABRI 3D	5	7.81
	Edmodo	2	3.12
	Game Tools	5	7.81
	GeoGebra	15	23.44
	Geometer’s Sketchpad	7	10.94
	Google Classroom	4	6.25
	Math Laboratory	7	10.94
	Moodle	3	4.69
	Power Point	3	4.69
	Zoom Meeting	3	4.69
Mathematical Content	Algebra	4	6.25
	Calculus	3	4.69
	Capita Selecta	17	26.56
	Geometry	20	31.25
	Measurement	3	4.69
	Number and Operations	7	10.94
	Statistics	6	9.37
	Trigonometry	4	6.25
Instrument Type	Essay	22	34.37
	Multiple Choice	42	65.62
The Role of Technology	Technology-based Learning	52	81.25
	Technology-assisted Learning	12	18.75

The process in extracting the data involved two experts in statistics. This matter was conducted to make sure that the data coded from each document to the coding sheet was valid and credible to be used [10, 107]. To perform it, Cohen's Kappa test was selected. In a literature, McHugh [116] formulated the calculation of Cohen's Kappa 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 categorized 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) [116]. The results of Cohen's Kappa test on statistical and categorical data are shown in Table 2.

Table 2. The results of Cohen's Kappa test

Items	Kappa Value	Agreement Level	Sig.
Mean of Experiment Group	0.973	Almost Perfect	0.002
Deviation Standard of Experiment Group	0.945	Almost Perfect	0.004
Sample Size of Experiment Group	0.987	Almost Perfect	0.001
Mean of Control Group	0.991	Almost Perfect	0.001
Deviation Standard of Control Group	0.962	Almost Perfect	0.003
Sample Size of Control Group	0.938	Almost Perfect	0.005
t-value	0.929	Almost Perfect	0.006
Class Capacity	0.897	Strong	0.011
Educational Level	0.835	Strong	0.027
Intervention Duration	0.843	Strong	0.019
Participant	0.878	Strong	0.016
Learning Environment	0.816	Strong	0.034
Technology Used	0.845	Strong	0.019
Mathematical Content	0.871	Strong	0.016
Instrument Type	0.839	Strong	0.028
The Role of Technology	0.861	Strong	0.018

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 in which it indicates that those coders significantly agree toward the statistical and categorical data coded from each document to the coding sheet. Moreover, it means that the statistical and categorical data checked by those coders are valid and credible to be used and then analyzed [83, 117].

E. Data Analysis

To calculate the effect size, the Hedge's equation was selected in that it facilitated the empirical studies which had relatively small sample size [107]. According to Borenstein *et al*. [118], 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 classified as 0.00–0.20 (weak), 0.21–0.50 (modest), 0.51–1.00 (moderate), and >1.00 (strong) [119]. Furthermore, the Z test was carried out to examine the significance of ICT-based or -assisted mathematics learning on students' numerical literacy. Additionally, the Cochran's Q test was performed to examine the involvement of substantial factors in differentiating students' numerical literacy in mathematics learning activities using ICT.

In a book chapter, Cooper *et al*. [108] explained that the statistical data in the meta-analysis study tended to become publication bias. As a consequence, few tests such funnel plot analysis and Rosenthal's FSN test were applied to ensure that before the valid and credible data were analyzed, those were avoided from the publication bias [10]. Moreover, Bernard *et al*. [120] also stated that the set of effect size tended to be sensitive on the change of the data quantity. The sensitivity to the set of effect size data means that there is an outlier or more when an effect size data is excluded from the set in which it is not good for the collection of effect size data that will be analyzed. Consequently, sensitivity analysis had to be carried out to make sure that the set of effect size data was not sensitive. The tool "one study removed" in Comprehensive Meta-Analysis (CMA) software was used to do it. All of calculations in this current study utilized CMA software version 3.0 [118].

IV. Results

A. Publication Bias and Sensitivity Analysis

To describe the distribution of effect size data, the funnel plot analysis was applied. From this funnel plot, subjectively, it can be stated that a set of effect size data in the plot was symmetrical (Fig. 2). This means that the statistical data used to calculate the effect size does not have the indication of publication bias. In a literature, Fuadi *et al.* [9] also explained that if the distribution of a set of effect size data in the funnel plot is symmetrical, it interprets that there is no publication bias to the statistical data.

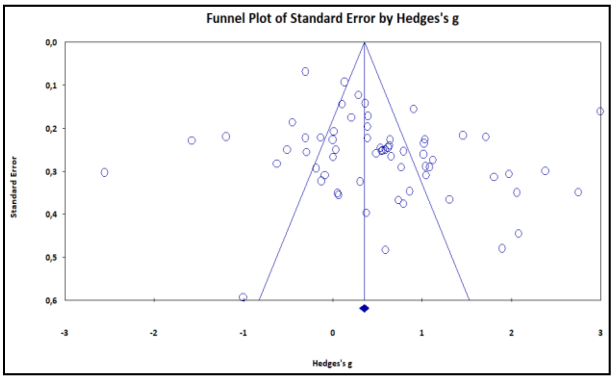

Fig. 2. The description of effect size distribution in the funnel plot.

Additionally, to confirm that the distribution of a set of effect size data in the plot was symmetrical, the Rosenthal's FSN test was applied (see Table 3).

Table 3. The results of the Rosenthal's FSN test

Items	Value
Z-value for observed studies	15.72
P-value for observed studies	0.00
Alpha	0.05
Number of observed studies	64
Number of missing studies that would bring p-value to more than alpha	4,053

From Table 3, it can be stated that the significance value of the Rosenthal's FSN test was less than 0.05 whereby this shows that a set of effect size data in the plot is resistant to publication bias. Moreover, Suparman *et al*. [83] stated that a significant value of the Rosenthal's FSN test indicates resistant effect size data to publication bias. This implicates that a set of effect size data used for this current study is resistant to publication bias and does not have the indication of publication bias.

To make sure the sensitivity of a set of effect size data toward the quantity change of effect size unit, sensitivity analysis might be carried out in which the tool "one study removed" in CMA software was utilized. The results reveal that the lowest g unit was 0.481 and the highest g unit was 0.574 while the combined effect size in *g* unit was 0.527 whereby this shows that the estimated effect size is located in the interval between 0.481 and 0.574. This interprets that there is no significant reaction of a set of effect size data on the quantity change of effect size unit. Bernard *et al*. [120] stated in a literature that if the estimated effect size is included between the lowest effect size and the highest effect size, the change of data quantity in effect size unit does not influence the sensitivity of a set of effect size data. So, this indicates that a set of effect size data involved in this recent study is not sensitive on the change of quantity.

B. Summarization and Estimation of Effect Size

The calculation of the statistical data selecting the Hedge's equation generated some heterogeneous effect sizes, from insignificant to significant, from weak until strong, and from negative to positive (See Table 4).

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

Document	Effect Size in *g* Unit	*z*-value	*p*-value
Hayati, 2001 [33]	0.618 [0.137; 1.099]	2.516	0.012
Choi *et al*., 2003a [54]	−0.307 [−0.744; 0.129]	−1.379	0.168
Choi *et al*., 2003b [54]	−0.137 [−0.571; 0.298]	−0.617	0.538
Mahmoudi *et al*., 2015 [121]	−0.295 [−0.797; 0.208]	−1.150	0.250
Saha *et al*., 2010a [45]	0.375 [−0.404; 1.155]	0.944	0.345
Saha *et al*., 2010b [45]	0.793 [0.056; 1.529]	2.108	0.035
Mensah and Nabie, 2021 [62]	0.639 [0.194; 1.084]	2.813	0.005
Bedada and Mechaba, 2022 [63]	0.792 [0.294; 1.289]	3.120	0.002
Zainil *et al*., 2019 [29]	0.561 [0.067; 1.054]	2.226	0.026
Zin *et al*., 2009 [30]	1.307 [0.589; 2.025]	3.566	0.000
Wolgemuth *et al*., 2011 [28]	0.394 [0.057; 0.731]	2.294	0.022
Liao *et al*., 2012 [32]	1.039 [0.472; 1.606]	3.591	0.000
Carr, 2012 [40]	0.386 [−0.000; 0.772]	1.958	0.050
Shin *et al*., 2012 [58]	−0.125 [−0.759; 0.508]	−0.388	0.698
Fagbemi *et al*., 2011 [42]	0.389 [−0.049; 0.828]	1.742	0.082
Ukdem and Cetin, 2022 [60]	−0.088 [−0.695; 0.520]	−0.283	0.777
Shin *et al*., 2006 [47]	0.307 [−0.329; 0.944]	0.946	0.344
O'Dwyer *et al.*, 2007 [44]	0.133 [−0.049; 0.315]	1.431	0.152
Bhagat *et al*., 2016a [39]	0.054 [−0.635; 0.743]	0.155	0.877
Bhagat *et al.*, 2016b [39]	0.862 [0.181; 1.542]	2.482	0.013
Bhagat *et al.*, 2016c [39]	0.591 [−0.358; 1.540]	1.221	0.222
Shadaan and Leong, 2013 [24]	1.080 [0.511; 1.650]	3.717	0.000
Tienken and Maher, 2008a [48]	−1.004 [−2.168; 0.159]	−1.692	0.091
Tienken and Maher, 2008b [48]	0.209 [−0.136; 0.553]	1.189	0.235
Tienken and Maher, 2008c [48]	0.066 [−0.631; 0.763]	0.185	0.853
Tienken and Maher, 2008d [48]	0.102 [−0.181; 0.384]	0.706	0.480
Idris, 2007 [34]	1.105 [0.504; 1.526]	3.893	0.000
Idris, 2006 [35]	1.715 [1.282; 2.148]	7.764	0.000
Jannah and Oktaviani, 2022 [61]	0.766 [0.194; 1.338]	2.627	0.009
Seferian *et al.*, 2021 [57]	−1.577 [−2.026; −1.128]	−6.884	0.000
Farhan *et al*., 2021 [65]	0.654 [0.132; 1.176]	2.454	0.014
Sumilat *et al*., 2022 [25]	0.905 [0.600; 1.211]	5.813	0.000
Dewi and Lestari, 2022 [52]	2.993 [2.676; 3.310]	18.522	0.000
Sarwar *et al*., 2022 [46]	0.011 [−0.397; 0.420]	0.055	0.956
Suparya *et al*., 2022 [73]	0.000 [−0.445; 0.445]	0.000	1.000
Agustina *et al*., 2021 [50]	−0.188 [−0.763; 0.388]	−0.640	0.522
Schoevers *et al*., 2020 [55]	−0.452 [−0.817; −0.086]	−2.422	0.015
Samritin *et al*., 2023 [56]	−0.512 [−1.004; −0.021]	−2.043	0.041
Ardinawan, 2022 [53]	−2.551 [−3.146; −1.957]	−8.412	0.000
Anggara *et al*., 2019 [51]	−1.194 [−1.625; −0.762]	−5.425	0.000
Adeyemi and Adaramola, 2014 [22]	0.362 [0.084; 0.641]	2.549	0.011
Widiastuti and Kurniasih, 2021 [27]	1.023 [0.561; 1.485]	4.340	0.000
Farahsanti and Exacta, 2016 [64]	0.532 [0.050; 1.015]	2.163	0.031
Manurung, 2015 [71]	1.030 [0.586; 1.475]	4.549	0.000
Sudiarta and Sandra, 2016a [38]	2.380 [1.792; 2.968]	7.933	0.000
Sudiarta and Sandra, 2016b [38]	1.805 [1.189; 2.420]	5.749	0.000
Nugraha *et al*., 2020 [36]	1.898 [0.957; 2.838]	3.953	0.000
Utami, 2017 [49]	0.001 [−0.522; 0.524]	0.004	0.997
Septian, 2017 [72]	1.972 [1.370; 2.574]	6.420	0.000
Ocal, 2017 [37]	0.590 [0.098; 1.081]	2.352	0.019
Eka *et al*., 2018 [69]	1.458 [1.032; 1.884]	6.707	0.000

Amir, 2018 [67]	1.045 [0.438; 1.651]	3.374	0.001
Hakim and Dalle, 2015 [66]	0.544 [0.047; 1.041]	2.145	0.032
Juandi and Priatna, 2018 [43]	0.033 [−0.459; 0.525]	0.131	0.895
Williams *et al.*, 2017 [41]	0.485 [−0.023; 0.993]	1.872	0.061
Jelatu *et al.*, 2018a [70]	0.734 [0.014; 1.455]	1.997	0.046
Jelatu *et al*., 2018b [70]	2.080 [1.207; 2.952]	4.670	0.000
Jelatu *et al*., 2018c [70]	1.120 [0.582; 1.659]	4.080	0.000
Bakar et al., 2010 [23]	0.635 [0.163; 1.108]	2.637	0.008
Bebell and Pedulla, 2015 [31]	0.289 [0.048; 0.530]	2.348	0.019
Stubbe *et al*., 2016 [59]	−0.308 [−0.442; −0.173]	−4.481	0.000
Diyarko and Waluya, 2016 [68]	2.750 [2.066; 3.435]	7.875	0.000
Rahman and Mahmud, 2018 [122]	−0.624 [−1.178; −0.070]	−2.209	0.027
Tay and Mensah-Wonkyi, 2018 [26]	2.062 [1.376; 2.747]	5.892	0.000
Estimated Effect Size	0.527 [0.309; 0.744]	4.748	0.000

Table 4 presents that the 53 eligible documents included in this recent study generated 64 units of effect size and 6,599 students. In detail, of those documents, there were three documents generating two units of effect size (e.g., Choi *et al*. [54]; Saha *et al*. [45]; Sudiarta and Sandra [38]), followed by two documents generating three units of effect size (e.g., Bhagat *et al*. [39]; Jelatu *et al.* [70]), and one document generating four units of effect size (e.g., Tienken and Maher [48]).

Moreover, units of the effect size were categorized to be three dimensions, such as direction, strength, and significance. The frequency distribution of effect size data viewed by those dimensions is presented in Fig. 3.

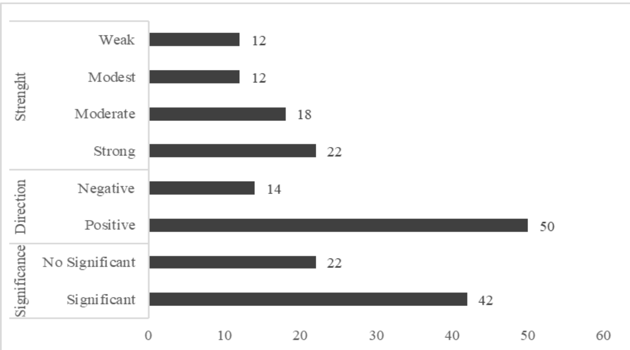

Fig. 3. The frequency distribution of effect size data based on strength, direction, and significance.

Fig. 3 presents that the data of effect size viewed by the strength consisted of 18.75% weak effect, 18.75% modest effect, 28.12% moderate effect, and 34.37% strong effect. Additionally, the data of effect size viewed by the direction consisted of 78.12% positive effect and 21.88% negative effect. Then, the data of effect size viewed by the significance consisted of 65.62% significant effect and 34.38% no significant effect. Of these reports, it can be stated that a set of effect size data is dominated by significant, positive, and strong effect size. Moreover, Table 4 shows that the estimated effect size was 0.527 in which this interprets that ICT-based or -assisted mathematics learning has moderate positive effect on students' numerical literacy. In addition, the significance value of the Z test was less than 0.05 whereby this shows that ICT-based or -assisted mathematics learning significantly cultivates students' numerical literacy. This means that ICT-based or -assisted mathematics learning is effective in cultivating students' numerical literacy.

C. Subgroup Analysis

The Q Cochrane test was applied to examine comprehensively some substantial factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology in differentiating students' numerical literacy in ICT-based or -assisted mathematics learning (See Table 5). Table 5 presents that the significance value of the Q Cochrane test for some substantial factors, such as educational level, learning environment, intervention duration, and instrument type was less than 0.05. This interprets that those factors significantly differentiate students' numerical literacy in mathematics learning activities using ICT. On the other hand, another significance value of the Q Cochrane test for several factors, such as class capacity, participant, mathematical content, technology used, and the role of technology was more than 0.05. This shows that there is no adequate evidence to state that the discrepancy of students' numerical literacy in ICT-based or -assisted mathematics learning is affected by these factors.

Table 5. The results of the Q Cochrane test

Substantial Factors	**Groups**	**Effect Size in *g* Unit**	**Heterogeneity**		
			***q*-value**	**df (*Q*)**	***p*-value**
Class Capacity	$n \leq 30$ (Small Class)	0.586	0.191	1	0.662
	$n > 30$ (Large Class)	0.487			
Educational Level	Primary School	0.233	5.586	2	0.041
	Secondary School	0.701			
	College/University	1.107			
Participant	African Students	0.604	7.549	4	0.110
	American Students	−0.094			
	Asian Students	0.700			
	Australian Students	0.394			
	European Students	0.012			
Intervention Duration	1–4 Weeks	−0.021	13.167	7	0.048
	5–8 Weeks	0.204			
	9–12 Weeks	0.616			
	13–16 Weeks	0.454			
	17–20 Weeks	−0.098			

	21–24 Weeks	0.913			
	25–48 Weeks	0.737			
	49–96 Weeks	1.420			
Learning Environment	Blended Learning	1.169	24.778	11	0.010
	Computer-based Learning	−0.064			
	Cooperative Learning (STAD)	0.476			
	Cooperative Learning (Jigsaw)	0.219			
	Cooperative Learning (NHT)	−0.078			
	Cooperative Learning (TSTS)	−0.037			
	Direct Learning	0.722			
	Discovery Learning	1.024			
	Game-based Learning	−0.115			
	Inquiry-based Learning	1.496			
	Problem-based Learning	0.598			
	Project-based Learning	1.345			
Technology Used	Adobe Flash	0.546	9.265	11	0.597
	Animation Video	0.595			
	CABRI 3D	0.802			
	Edmodo	0.870			
	Game Tools	0.566			
	GeoGebra	0.942			
	Geometer's Sketchpad	0.333			
	Google Classroom	0.722			
	Math Laboratory	−0.063			
	Moodle	0.500			
	Power Point	0.011			
	Zoom Meeting	−0.314			
Mathematical Content	Algebra	0.997	9.103	7	0.245
	Calculus	1.107			
	Capita Selecta	0.297			
	Geometry	0.769			
	Measurement	−0.497			
	Number and Operations	0.397			
	Statistics	0.371			
	Trigonometry	0.645			
Instrument Type	Essay	0.847	4.406	1	0.036
	Multiple Choice	0.362			
The Role of Technology	Technology-based Learning	0.425	0.184	1	0.668
	Technology-assisted Learning	0.550			

V. Discussion

A. The Effect of ICT-Based or -Assisted Mathematics Learning on Numerical Literacy

This recent study reports that of the estimated effect size, overall, ICT-based or -assisted mathematics learning had moderate positive effect on students' numerical literacy. This implicates that the utilization of ICT in mathematics learning activities can be an effective solution for students' numerical literacy. Some previous meta-analysis studies also revealed that computer technology-assisted mathematics learning had moderate positive effect on students' mathematics achievement [9, 10, 13, 86]. Additionally, Li *et al*. [89] found that the use of mathematics software in mathematics learning activities had moderate positive effect on students' mathematics learning outcome. Even, a few meta-analysis studies found that mathematics software-assisted mathematics learning had strong positive effect on students' mathematics learning outcome [91, 103]. Particularly, the utilization of a few of specific mathematics software, such as DGS and CAS had moderate positive effect on students' geometric and algebraic achievement [93, 104]. More specific, regarding DGS, CABRI 3D-assisted geometry lesson had moderate positive effect on students' geometry achievement [11, 101], and GeoGebra-assisted algebra lesson had moderate positive effect on students' algebra achievement [96, 97]. These reports provide adequate evidence to state that ICT-based or -assisted mathematics learning can be an effective solution for students' numerical literacy.

Moreover, this current study reports that ICT-based or -assisted mathematics learning significantly cultivated students' numerical literacy. This was line to some meta-analysis studies that computer technology-assisted mathematics education significantly enhanced students' mathematics achievement [84, 85, 87, 88]. In addition, a few of meta-analysis studies showed that the utilization of mathematics software in mathematics learning activities significantly enhanced students' mathematics learning outcome [89, 91, 103]. More specific, some meta-analysis studies found that the utilization of DGS and CAS in geometry and algebra learning significantly cultivated students' geometric and algebraic achievement [81, 92, 94, 104]. Even related to DGS, a few studies revealed that CABRI 3D-assisted geometry learning significantly cultivated students' geometry achievement [11, 101], and GeoGebra-assisted algebra learning significantly enhanced students' algebra achievement [96–98]. Of these reports, it can be stated that there is strong evidence to state that ICT-based or -assisted mathematics learning significantly cultivate students' numerical literacy. Consequently, the utilization of ICT in mathematics learning activities can be an effective way in enhancing students' numerical literacy.

The rapid development of ICT in the 21st-century has a fundamental role in mathematics education, particularly in cultivating or enhancing mathematics skills and abilities. ICT offers a variety of features in promoting the activities of mathematics learning whereby it helps facilitators, such as teacher and lecturer in explaining mathematical contents, such as geometry, algebra, number and operations, statistics and probability, trigonometry, and others. Moreover, it also makes students easy in learning and understanding the presented mathematics materials or topics. This reason can be done in that ICT enables in constructing innovative and creative learning media. As a consequence, this learning media creates mathematics learning to be well undergoing and interesting [77, 123]. Furthermore, Phuong *et al.* [123] explained that an interesting mathematics lesson besides enhancing students' motivation and interest, it also helps in constructing students' knowledge and understanding in mathematics. More particular, Dokic *et al*. [124] stated that students' knowledge and understanding that have been constructed will generate basic skills and also advanced skills whereby numerical literacy is one of basic skills in mathematics. This means that the utilization of ICT in mathematics learning activities can be a stimulant element for students in cultivating their numerical literacy skills. This stimulus, however, can't undergo without the required technological knowledge of users. This implicates that the sophisticated technology must be followed by adequate technology competence of users, such as student, teacher, or lecturer in operating these technological tools.

Generally, the utilization of ICT in educational field has three main functions consisting of interactive Compact Disk (CD), learning aids like as the use of learning software, and learning sources in internet form with all of components [79, 80]. Moreover, particularly in mathematics education, Valverde-Berrocoso *et al*. [17] mentioned that ICT has two mainly fundamental roles, such as ICT-based mathematics learning and ICT-assisted mathematics learning. In detail, ICT-based mathematics learning facilitates students and also teachers to do many activities during the process of mathematics learning. Several online platforms, such as Google classroom, Edmodo, Moodle, Zoom, Sociology, and others can be utilized to promote distance learning [125, 126]. Meanwhile, ICT-assisted mathematics learning accommodates students and teachers in carrying out some activities on certain parts in the process of mathematics learning. In certain parts of mathematics learning activities, they use some mathematics software, such as DGS and CAS which facilitate them in presenting and explaining mathematical contents, and understanding mathematics concepts and solving mathematics problems [21, 127]. Specifically, a few of dynamic geometry software, such as CABRI-3D and GeoGebra can facilitate teachers in presenting and explaining algebra and geometry materials and make easy students in understanding algebra and geometry concepts and solving algebra and geometry problems [128, 129]. Through the mathematics software, on several mathematical contents, students can cultivate their skills in using a variety of numbers and symbols related to basic mathematics to solve various daily contextual problems, analyzing the presented information in various forms, such as graph, table, chart, and others, and interpreting analysis results to make predictions and decisions [2, 5, 6]. All of these skills describe numerical literacy. So, the use of ICT in a lot of mathematics learning environments can be an effective intervention in cultivating students' numerical literacy.

B. Heterogeneity of Students' Numerical Literacy in ICT-Based or -Assisted Mathematics Learning

The gap of students' numerical literacy in ICT-based or -assisted mathematics learning has been investigated by proposing some substantial factors, such as class capacity, educational level, participant, intervention duration, learning environment, technology used, mathematical content, instrument type, and the role of technology to be examined in this current study. In detail, the results of examination are explained and discussed in the following subsections.

1) Class capacity

The factor of class capacity was categorized to be two groups, such as small class ($n \leq 30$ participants) and large class ($n > 30$ participants). This recent study shows that there was no sufficient evidence to state that class capacity affects the difference of students' numerical literacy in ICT-based or -assisted mathematics learning. A few of meta-analysis studies also revealed that the factor of class capacity was not significant factor in differentiating students' mathematics achievement in DGS -assisted mathematics learning [78, 96]. These reports strengthen that the factor of class capacity is not significant factor in differentiating students' numerical literacy in mathematics learning activities utilizing ICT. Additionally, this current study also shows that the ICT-based or -assisted mathematics learning had moderate positive effect on students' numerical literacy in small classroom and modest positive effect on students' numerical literacy in large classroom. This means that the use of ICT in small mathematics classroom is more effective in enhancing students' numerical literacy than the use of ICT in large mathematics classroom. A few of meta-analysis studies also showed that the utilization of DGS, such as CABRI 3D and GeoGebra in small geometry and algebra lesson was more effective in enhancing students' mathematics achievement than the utilization of DGS in large algebra and geometry lesson [11, 97]. This implicates that the facilitators, such as teacher and lecturer should organize students to learn in small ICT-based or -assisted mathematics classroom in cultivating students' numerical literacy.

2) Educational level

The factor of educational level was categorized to be three groups, such as primary school, secondary school, and college/university. This current study finds that the factor of educational level significantly differentiates students' numerical literacy in ICT-based or -assisted mathematics learning. A few of meta-analysis studies also showed that there was significant evidence to state that educational level affected the heterogeneity of students' mathematics achievement in computer technology-assisted mathematics learning [9, 10]. These reports provide adequate evidence to state that educational level is one of substantial factors that must be considered by teacher and lecturer in implementing ICT-based or -assisted mathematics learning to enhance students' numerical literacy. In addition, this recent study also finds that ICT-based or -assisted mathematics learning had modest positive effect on primary students' numerical literacy, moderate positive effect on secondary students' numerical literacy, and strong positive effect on college students' numerical literacy. This presents that the intervention of ICT-based or -assisted mathematics learning in college/university is more effective in cultivating students' numerical literacy than in primary school or secondary school. A few of meta-analysis studies also revealed that the use of computer technology-assisted mathematics learning for students' mathematics achievement was more effective in college/university than elementary school, middle school, or high school [84, 85]. These findings indicate that college/university students have higher technological content knowledge in using ICT in mathematics learning activities than primary or secondary students.

3) Participant

The factor of participant was categorized to be five groups, such as Asian students, American students, African students, Australian students, and European students. This recent study reveals that there was no sufficient evidence to state that the factor of participant differentiated students' numerical literacy in ICT-based or -assisted mathematics learning. Li *et al*. [89] in a literature also revealed that the heterogeneity of students' mathematics learning outcome in mathematics software-assisted mathematics learning was not differentiated by the factor of participant. This shows that the difference of students' school geographical location does not generate students' heterogeneous numerical literacy in ICT-based or -assisted mathematics learning. Suparman *et al*. [106] also showed that the heterogeneity of students' mathematical critical thinking skills in technology -assisted problem-based learning was not caused by the factor of school geographical location. Moreover, this recent study also reveals that ICT-based or -assisted mathematics learning had weak positive effect on European students' numerical literacy, modest positive effect on Australian students' numerical literacy, moderate positive effect on African and Asian students' numerical literacy, and weak negative effect on American students' numerical literacy. Even, the effect of ICT-based or -assisted mathematics learning on Asian students' numerical literacy was higher than the effect of ICT-based or -assisted mathematics learning on African students' numerical literacy. This shows that the treatment of ICT-based or -assisted mathematics learning is more effective in enhancing Asian students' numerical literacy than African, American, Australian, and European students' numerical literacy.

4) Intervention duration

The factor of intervention duration was categorized to be eight groups, such as 1–4 weeks, 5–8 weeks, 9–12 weeks, 13–16 weeks, 17–20 weeks, 21–24 weeks, 25–48 weeks, and 49–96 weeks. This current study shows that the factor of intervention duration significantly differentiated students' numerical literacy in ICT-based or -assisted mathematics learning. A few of meta-analysis studies also found that the gap of students' algebra achievement in GeoGebra-assisted algebra learning was significantly affected by the factor of intervention duration [81, 94]. This indicates that the facilitators, such as teacher and lecturer have to consider intervention duration decided in ICT-based or -assisted mathematics learning as an important factor in cultivating students' numerical literacy. Furthermore, this current study also shows that ICT-based or -assisted mathematics learning had weak negative effect on students' numerical literacy treated during 1–4 weeks and 17–20 weeks, modest positive effect on students' numerical literacy treated during 5–8 weeks and 13–16 weeks, moderate positive effect on students' numerical literacy treated during 9–12 weeks, 21–24 weeks, and 25–48 weeks, and strong positive effect on students' numerical literacy treated during 49–96 weeks. This shows that students' numerical literacy treated by ICT-based or -assisted mathematics learning during 49–96 weeks is higher than students' numerical literacy treated by ICT-based or -assisted mathematics learning during other intervention durations. This implicates that mathematics teacher or lecturer should allocate the maximum intervention duration to cultivate students' numerical literacy in mathematics learning activities using ICT.

5) Learning environment

The factor of learning environment was categorized to be twelve groups, such as blended learning, computer-based learning, cooperative learning (e.g., STAD, Jigsaw, NHT, & TSTS), direct learning, discovery learning, game-based learning, inquiry-based learning, problem-based learning, and project-based learning. This present study finds that there was significant evidence to state that the factor of learning environment differentiated students' numerical literacy in ICT-based or -assisted mathematics learning. Li and Ma [86] in a literature also revealed that learning environment significantly affected the difference of students' mathematics achievement in computer technology-assisted mathematics learning. Consequently, the facilitators, such as teacher and lecturer must consider the type of learning environment as an essential factor in implementing ICT-based or -assisted mathematics learning to promote the enhancement of students' numerical literacy. Moreover, this present study also finds that the use of ICT in computer-based learning, cooperative learning (NHT & TSTS), and game-based learning had weak negative effect on students' numerical literacy while the use of ICT in cooperative learning (STAD & Jigsaw) had modest positive effect on students' numerical literacy. Additionally, the utilization of ICT in direct learning and problem-based learning had moderate positive effect on students' numerical literacy whereas the utilization of ICT in blended learning, discovery learning, inquiry-based learning, and project-based learning had strong positive effect on students' numerical literacy. Even, the effect of ICT-assisted inquiry-based learning on students' numerical literacy was higher than the effect of ICT-assisted other learning environments on students' numerical literacy. This shows that ICT combined to inquiry-based learning is more effective in enhancing students' numerical literacy than ICT combined to other learning environments. As a consequence, mathematics teacher or lecturer can select ICT-assisted inquiry-based learning to be alternative way to cultivate students' numerical literacy in mathematics learning activities.

6) Technology used

The factor of technology used was categorized to be twelve groups, such as Adobe Flash, animation video, CABRI 3D, Edmodo, game tools, GeoGebra, Geometer's Sketchpad, Google classroom, math laboratory, Moodle, power point, and zoom meeting. This recent study reveals that there was no sufficient evidence to state that the factor of technology used affected the gap of students' numerical literacy in ICT-based or -assisted mathematics learning. Some previous meta-analysis studies also revealed that students' heterogeneous mathematics achievement in computer technology-assisted mathematics learning was not caused by the factor of technology used [98, 103, 130]. This interprets that whatever technology used in mathematics learning, it can cultivate students' numerical literacy. Furthermore, this recent study reveals that math lab & power point-assisted mathematics learning had weak positive and negative effect on students' numerical literacy. This shows that math lab and power point have not had the significant role in supporting mathematics educator to enhance students' numerical literacy. Meanwhile, zoom-based & geometer's sketchpad-assisted mathematics learning had modest positive and negative effect on students' numerical literacy. This also reveals that zoom application and geometer's sketchpad software have not had the significant effect in promoting mathematics teacher or lecturer to enhance students' numerical literacy. Additionally, Moodle, Google classroom, & Edmodo-based and Adobe Flash, animation video, CABRI 3D, game tools, & GeoGebra-assisted mathematics learning had moderate positive effect on students' numerical literacy. This presents that some online learning platforms, such as Moodle, Google classroom, and Edmodo, and some applications, such as Adobe Flash, CABRI 3D, GeoGebra, animation video, and game tools have the significant role and effect in promoting mathematics educator to enhance students' numerical literacy. Of all technologies, GeoGebra-assisted mathematics learning had the highest effect on students' numerical literacy. This shows that the use of GeoGebra in mathematics learning is more effective in cultivating students' numerical literacy than the use of other technologies in mathematics learning.

7) Mathematical content

The factor of mathematical content was categorized to be eight groups, such as algebra, calculus, capita selecta, geometry, measurement, number & operations, statistics, and trigonometry. This current study finds that the gap of students' numerical literacy in ICT-based or -assisted mathematics learning was not affected by the factor of mathematical content. Juandi *et al*. [12] in a literature also found that there was no adequate evidence to state that mathematical content differentiated students' mathematical critical thinking skills in technology-assisted problem-based learning. This presents that whatever mathematical content involved in mathematics learning environment, students' numerical literacy can be cultivated in ICT-based or -assisted mathematics learning. Moreover, this current study finds that ICT-based or -assisted mathematics learning had modest positive and negative effect on students' numerical literacy in some courses, such as capita selecta, measurement, number & operations, and statistics, moderate positive effect on students' numerical literacy in some courses, such as algebra, geometry, and trigonometry, and strong positive effect on students' numerical literacy in calculus course. This shows that ICT-based or -assisted mathematics learning has the highest effect on students' numerical literacy in calculus course. This means that ICT-based or -assisted calculus course is more effective in enhancing students' numerical literacy than ICT-based or -assisted other mathematics courses.

8) Instrument type

The factor of instrument type was categorized to be two groups, such as essay and multiple choice. This present study reveals that there was significant evidence to state that the factor of instrument type differentiated students' numerical literacy in ICT-based or -assisted mathematics learning. A few of meta-analysis studies also revealed that the factor of instrument significantly differentiated students' mathematics achievement in computer technology-assisted mathematics learning [86, 88]. This shows that the facilitators, such as teacher and lecturer have to consider instrument type used to measure students' numerical literacy as an important factor in implementing ICT-based or -assisted mathematics learning. Furthermore, this present study also reveals that ICT-based or -assisted mathematics learning using essay as a mathematics instrument had moderate positive effect on students' numerical literacy while ICT-based or -assisted mathematics learning using multiple choice as a mathematics instrument had modest positive effect on students' numerical literacy. This indicates that the use of essay as an instrument model to measure students' numerical literacy in ICT-based or -assisted mathematics learning is more effective than the use of multiple choices. Akcay *et al.* [88] in a literature also explained that the use of essay as an instrument to measure students' mathematics achievement in computer technology-assisted mathematics learning was more valid than the use of multiple choice. This implicates that mathematics teachers or lecturers should use essay model as an instrument to measure students' numerical literacy in ICT-based or -assisted mathematics learning.

9) The role of technology

The factor of technology role was categorized to be two groups, such as technology-based learning and technology-assisted learning. This recent study presents that there was no adequate evidence to state that the factor of technology role differentiated students' numerical literacy in ICT-based or -assisted mathematics learning. Some previous meta-analysis studies also found that the factor of technology role did not differentiate students' mathematics achievement in computer technology-assisted mathematics learning [84, 85, 92, 99]. This shows that whatever the role of technology in mathematics learning activities, it does not generate the gap of students' numerical literacy. Furthermore, this recent study also presents that ICT-based mathematics learning had modest positive effect on students' numerical literacy while ICT-assisted mathematics learning had moderate positive effect on students' numerical literacy. This shows that ICT-assisted mathematics learning is more effective in enhancing students' numerical literacy than ICT-based mathematics learning. ICT as an assistant tool in mathematics learning activities can be promoted by some mathematics software, such as GeoGebra, geometer's sketchpad, math lab, CABRI 3D, adobe flash, animation video, and others. Meanwhile, ICT as a basic tool in mathematics learning activities can be supported by some online platforms, such as zoom meeting, Moodle, Edmodo, Google classroom, and others. Both mathematics software and online platform has a fundamental role in mathematics learning in facilitating distance learning and explaining several mathematical contents [15–17]. Consequently, these technological tools help the facilitators, such as teacher and lecturer in cultivating or enhancing students' numerical literacy.

C. Limitation and Suggestion

There are some limitations found by us in carrying out this current meta-analysis study. A lot of prospective documents identified in several search engines can't be accessed because the documents are restricted by publishers. As a consequence, we have to pay it to get the access of those documents. Additionally, many documents also do not report adequate information regarding statistical data, such as mean, standard deviation, sample size, *t*-value, and *p*-value to compute units of effect size. For further relevant studies, we suggest that 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.

VI. Conclusion and Implication

This recent meta-analysis study has estimated that ICT-based or -assisted mathematics learning has moderate positive effect on the cultivation of students' numerical literacy. Additionally, this meta-analysis study also has examined that there is significant evidence to state that ICT-based or -assisted mathematics learning cultivates students' numerical literacy. This implicates that the utilization of ICT in the activities of mathematics learning can be an effective way to cultivate students' numerical literacy. The use of mathematics software, such as DGS and CAS can facilitate students and teachers in geometry and algebra lesson whereby DGS and CAS promote teachers in presenting and explaining geometry and algebra topic so that it can make easy students in understanding algebra and geometry concepts and solving algebra and geometry problems. Additionally, the use of online platforms, such as Zoom meeting, Google classroom, Moodle, Edmodo, and others can facilitate the activities of distancing mathematics learning. All of technological supports are projected to the cultivation of students' numerical literacy as a basic skill in mathematics.

Regarding students' heterogeneous numerical literacy, this present meta-analysis study has examined that some substantial factors, such as educational level, intervention duration, learning environment, and instrument type differentiate students' numerical literacy in ICT-based or -assisted mathematics learning. However, there is no adequate evidence to state that several other substantial factors, such as class capacity, participant, mathematical content, technology used, and technology role affect the difference of students' numerical literacy in mathematics learning activities using ICT. This implicates that the facilitators, such as teacher and lecturer have to consider the significant factors in selecting and deciding educational policies in ICT-based or -assisted mathematics learning for students' numerical literacy. They should enhance primary and secondary students' technological content knowledge in that college/university students have higher technological content knowledge in using ICT in mathematics learning activities than primary or secondary students. Additionally, they also should allocate the maximum intervention duration to cultivate students' numerical literacy in mathematics learning activities using ICT. Moreover, they can select ICT-assisted inquiry-based learning to be alternative way to cultivate students' numerical literacy in mathematics learning activities. In addition, they also should use essay model as an instrument to measure students' numerical literacy in ICT-based or -assisted mathematics learning.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yetti Ariani, Melva Zainil, and Rahmatina 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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