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ORIGINAL PAPER

Meta-Analysis: Effectiveness of ICT-Based Learning Model on Students' Mathematical Ability

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Abstract
The purpose of this study is to determine the effectiveness of the ICT learning model on students' mathematical potential. The type of research used is meta-analysis. The Publish or Perish (PoP) database and Google Scholar were reviewed to achieve appropriate research within the scope of the study. By inputting keywords that have been in this database, I found approximately 200 articles that were published between 2014 and 2023 and have been researched for research targets. Based on the inclusion requirements, 22 articles have met the suitability requirements for research. The software used as an analysis tool is Comprehensive Meta-Analysis (CMA) version 3.7, and the effect size index from the Hedges-g Coefficient equation was obtained from the determination through the estimated random-effects design. The results of the study found that the overall effect size of ICT use on students' mathematical ability was 0.498 with a 95% confidence level. This finding indicates that the use of ICT in Indonesia or abroad is still quite effective because it has a positive impact on students' mathematical ability. Thus, the application of ICT has a greater effect on mathematical ability than the conventional approach.

Keywords:
Meta-Analysis
ICT
Mathematical Ability

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INTRODUCTION

The use of technology in mathematics learning is a necessity in line with the development of innovation in the field of education (Maarif et al., 2018). The rapid development of information and communication technology (ICT) means that mathematics teachers have to really innovate with challenges or obstacles to the use of learning media based on the development of technology (Amuko et al., 2015). Human civilisation has created new traditions and cultures caused by the development of science and technology or science and technology. One proof of the development of science and technology is the advancement of information technology (ICT). There is a very wide impact due to ICT supported by electronic technology in several fields, including the education sector. The education system in Indonesia is always experiencing development with the aim of realizing a quality education system. To keep up with current technological developments, ICT-based learning media (Information Communication and Technologies) is urgently needed to support various technological needs such as sending, processing, storing, producing, displaying, or distributing information electronically, collectively called ICT (Arfiyani et al., 2022).

ICT has proven to play an important role in learning. Many educational units in Indonesia are trying to improve ICT facilities in the classroom, such as the availability of computers and internet connections. Apart from being the object of study, ICT plays a role as a learning tool (Gil-Flores et al., 2017). Software programs include a section of ICT that is useful to students. The software is designed for a variety of purposes, including creating graphics, managing data, and completing calculations.

One of the subjects that is considered difficult is mathematics (Tasdik & Amelia, 2021). Mathematics is called a science that expresses its vision in two directions, namely, elaborating the needs of the present and elaborating the needs of the future (Supinah & Soebagyo, 2022). Learning using technology helps students develop their understanding of mathematics practices and mathematics teaching methods for teachers (Muhtadi et al., 2018). This statement is similar to the statement (Sivakova et al., 2017) that the implementation of ICT in mathematics learning makes it easier for students to understand mathematical concepts and techniques. Therefore, to achieve better learning activities, an effective learning model for students is needed, such as the application of the ICT learning model.

In research conducted by several previous researchers, the application of ICT in learning is included in actions to improve students' mathematical skills. Student proficiency is also required when using technology. The first step to minimise these problems is to use ICT-based geogebra learning media. The use of technology in the classroom, such as geogebra software, which is expected to present more interesting and memorable forms of images or animations, is one way to improve students' mathematical skills. This can make the learning process more fun and less boring (Arfiyani et al., 2022). Thus, mapping some research results regarding ICT through meta-analysis captivates researchers.

Meta-analysis is a method that functions as a combination, review, and summary of previous research by abstracting two or more research findings. In addition, meta-analysis functions to investigate various questions according to the data that has been received from previous research results. One of the necessary conditions when conducting meta-analysis research is learning from several similar research results (Nieuwenstein et al., 2015; Paldam, 2015). In addition, meta-analysis is also a quantitative elaboration where it takes a rather large amount of data and the application of statistical methods by practising it in structuring a number of information from a large sample in order to refine several other purposes so as to structure and obtain as much information as possible from the acquisition of data. Based on primary collection, meta-analysis is also used as a technique to re-analyze and statistically process some of the research results (Glass, 1974; Hedges, 1982).

One of the studies that examined meta-analysis related to the impact of the learning model on students' mathematical abilities (Mayasari et al., 2022). The conclusion accepted is that electronic learning media provides a medium to high category of effect measures from learning outcomes and students' understanding of concepts. The average results of the measure of the effect of electronic learning media on learning outcomes and the average result of the measure of the effect of electronic teaching materials on students' understanding of concepts are categorised as very high because the results obtained are 1.3 and 1.49. The results of the analysis show that electronic teaching materials have a very high influence on improving learning outcomes and students' understanding of concepts. So, the novelty of the research that will be carried out here is related to the meta-analysis of the effectiveness of ICT-based learning on students, with 22 primary data points obtained through literature studies using Google Scholar and high school levels in Indonesia.

This meta-analysis is necessary to evaluate the implementation of the ICT learning model to see the overall development clearly and also consider the implications. Thus, this research will directly contribute to the science and practice of ICT in the future, especially in educational settings. This study expressly answers two questions, namely: (1) Is the average effectiveness of the measure of presenting the background of each ICT learning model in high school significantly different from zero? (2) Whether there are differences in the effects of ICT implementation based on categorical variables.

METHOD

This research focuses on the use of data meta-analysis methods by reviewing several articles from international journals, national journals, international proceedings, and national proceedings. Meta-analysis methods, according to (Kavale & Glass, 1981 Soetjipto, 1995), one of the analytical methods related to the conclusion of various quantitative research results in a similar discussion involving the use of significant quantitative data and the implementation of statistical methods to compile information from a large sample is useful to complement other objectives through the provision of a more comprehensive understanding through the acquisition of data organisation. The research reviewed is related to ICT-based learning and students' mathematical ability. Effect measures are a simple way to assess the differences between two groups with multiple advantages rather than involving statistical significance tests (Tamur et al., 2020). Borenstein et al. (2021) explained three stages related to meta-analysis: First, the analysed study has a provision of calculated criteria. Second, an explanation related to the procedure for collecting observation data and research variables. Third, explanations related to statistical techniques.

Journal Collection

Bibliometric analysis is a method used in library science to find scientific publications in relation to scientific citations (Rohanda & Winoto, 2019). In this study, bibliometric analysis is a reference source in taking the results of collecting articles in the Publish or Perish (PoP) application based on search results using the keyword "ICT-based learning, mathematical ability." Two hundred articles were found to be followed up on. Furthermore, the articles that have been identified are in the form of variable coding sheets referred to as meta-analysis instruments. Based on the results of the meta-analysis, 22 articles met the inclusion criteria.

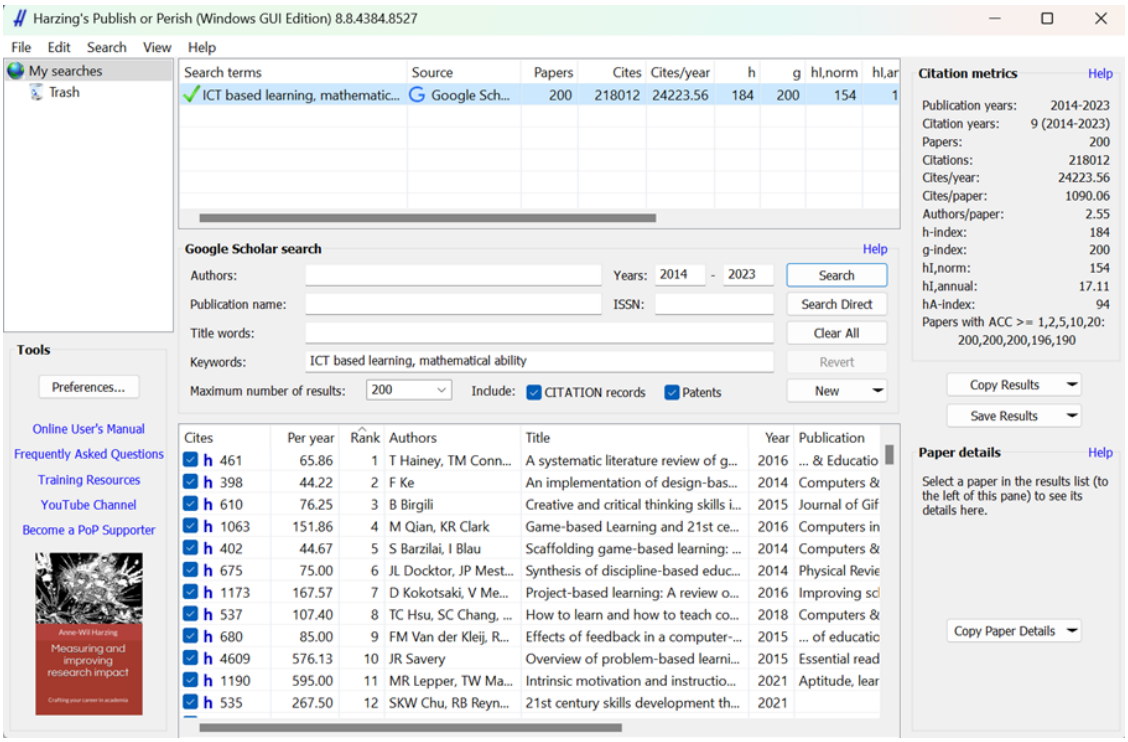

Figure 1. Figure 1. Search results for ICT-based learning journals using PoP

Based on Figure 1, the search results from the next PoP to complete the data obtained were analysed using the Comprehensive Meta-Analysis (CMA) version 3.7 application. They collected primary data, namely articles related to ICT learning methods within 10 years.

Journal Criteria

In this study, there is an examination and assessment of research articles related to the initial search to be substituted into meta-analysis with the following criteria: 1) The year of publication starts from 2012 to 2023, 2) Published articles involving international journals, national journals, national proceedings, international proceedings, and those indexed by SINTA, 3) Research articles are the results of experiments. The experimentation of the ICT-Based Learning model and other models that serve as the control group, and 4) The data reported in the research article is sufficient for effect size conversion.

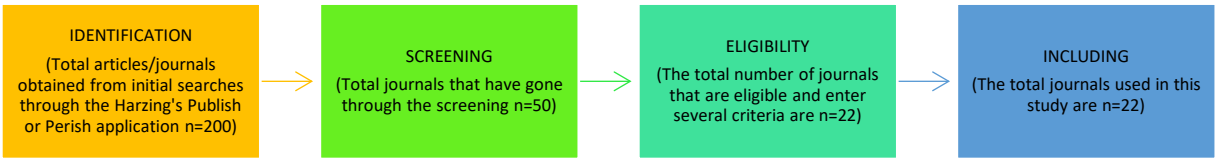

Figure 2. Data filtering based on PRISMA

Figure 2 shows the process of filtering journals using PRISMA, which will be used in the research. The number of journals that will be used is 22.

Coding

Coding is the most important requirement in meta-analysis to facilitate data collection and analysis. Therefore, this meta-analysis instrument is carried out using a coding formula or Coding Category (Asror, 2018). Journals obtained from the Google Scholar database will be tested to produce research related to the keywords "ICT-Based Learning" and "Mathematics Ability". Two hundred articles were generated at this stage and published between 2012 and 2023. Furthermore, the article is checked for research needs. In addition, a meta-analysis instrument in the form of a variable coding sheet has been developed to find the articles that have been collected. The coding using research instruments involved two students. The existence of a form of coding in the coding form is designed according to the characteristics that have been adjusted, namely the name of the researcher, the title of the study, the year of the study, the size of the research sample, the software used in the research, and the mean value, the standard of analysis, as well as the number of class samples from the control class obtained from the post-test.

Statistical Analysis

The data will be analysed through Comprehensive Meta-Analysis (CMA) software, which analyses data to change the effect size of each article. This study uses a measure of the effect of collecting articles that are studied through the keywords "ICT-Based Learning" and "Mathematical Ability". The collected data will be analysed through the Comprehensive Meta-Analysis (CMA) software. Good measurements of the population resulted from Cohen's equations, where a small sample biased the publication towards the article. This study uses Cohen's equation for sizing effects by considering

variations in sample size between articles. Interpretation of effect size using Cohen's classification (Cohen et al., 2017), namely <0.2 (ignored), 0.2-0.5 (small effect), 0.5-0.8 (moderate effect), 0.8-1.3 (large effect), and >1.3 (very large effect).

A statistical examination of the Q and P-values was used to test heterogeneity. The effect measure of each study was rejected when it was stated that the null hypothesis of all studies was homogeneous, with a p<0.05 value. Thus, the estimate taken was a random-effect type. The null hypothesis was accepted, and the fixed-effect type was assessed when the p>0.05 value (Çoğaltay & Karadağ, 2015). Publication bias checks aim to prevent misrepresentation in the context of findings. Articles that have been published are more likely to be substituted in meta-analysis because they are considered significant (Tamur et al., 2023). To calculate before this happens, the funnel plot is examined to assess the probability of the number of biases, and Rosenthal's FSN statistics serve to assess the impact of bias (Tamur et al., 2020). It was stated that it was not affected by bias in this study. The spread of the effect size illustrates the results of proportional spread around the vertical line (Borenstein et al., 2021). However, if the reality is that the size of the effect is not the same, it is possible to use the trim and fill procedure. Therefore, if it is known that the effects observed by the type of random effect are the same, then the study is not affected by publication bias (Tamur et al., 2023).

RESULTS AND DISCUSSION

Result

Figure 3 is a research plot containing the study name, standard diff in means, standard error, variance, lower limit, upper limit, z-value, and p-value. The results of this study are useful for answering the first question presented. The effect size of each of these studies is heterogeneous because of the breadth of the level of trust and the inconsistency of the response rate. It is important to check that the estimation method is correct with the initial assumptions.

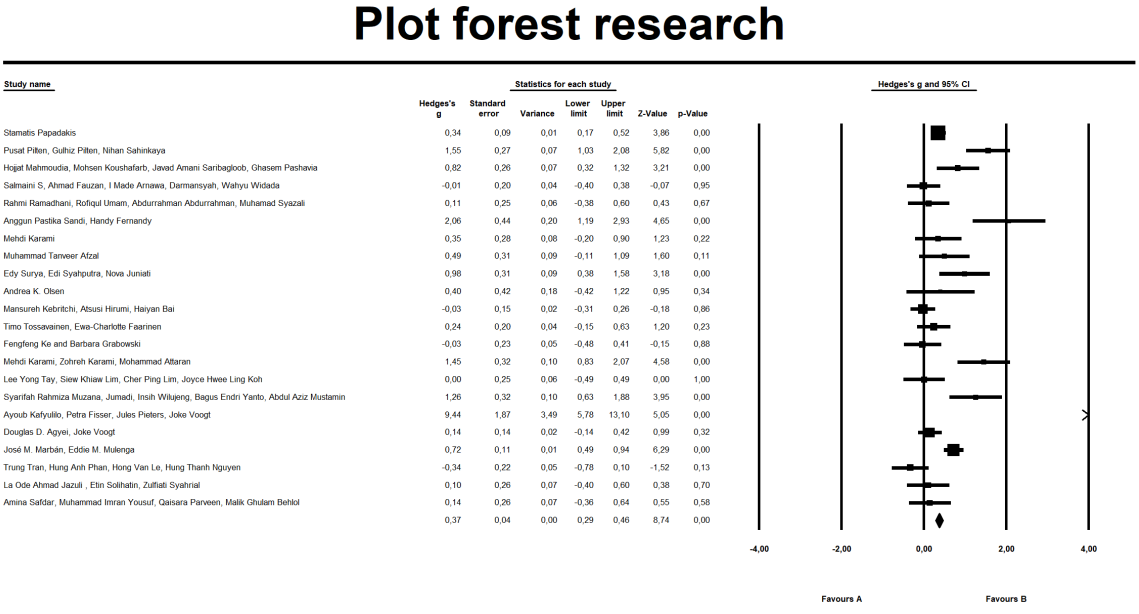

Figure 3. Plot Forest Research

Table 1 displays a summary of the analysis to answer question 1 and determine the estimation method.

Table 1. Comparison of Results Based on Estimation Model

No	Estimation Model	n	Z	p	Effect Size	Standard Error	95% CL		Q_b	p-value	I-squared
							Lower Limit	Upper Limit			
1	Fixed Effects	22	8,723	0,000	0,376	0,043	0,291	0,460	126,675	0,000	83,422
2	Random Effects	22	4,288	0,000	0,498	0,116	0,270	0,726			

Table 1 shows that the P value < 0 means that the effect size distribution for each study is heterogeneous, where the population estimation method in this study is in accordance with the random-effect model. This table also shows the results of hypothesis testing to answer research question 1. It can be seen that in Table 1, the P value for the null test < 0 is based on the random-effects model. It can be interpreted that the overall research results clarify the advantages of the Based Learning group. The overall effect size, according to the random effect model, is 0.498, which is classified as a small effect (Cohen et al., 2017). Furthermore, it is important to calculate whether the overall effect measure is tied to the publication bias, and then the study funnel plot is observed.

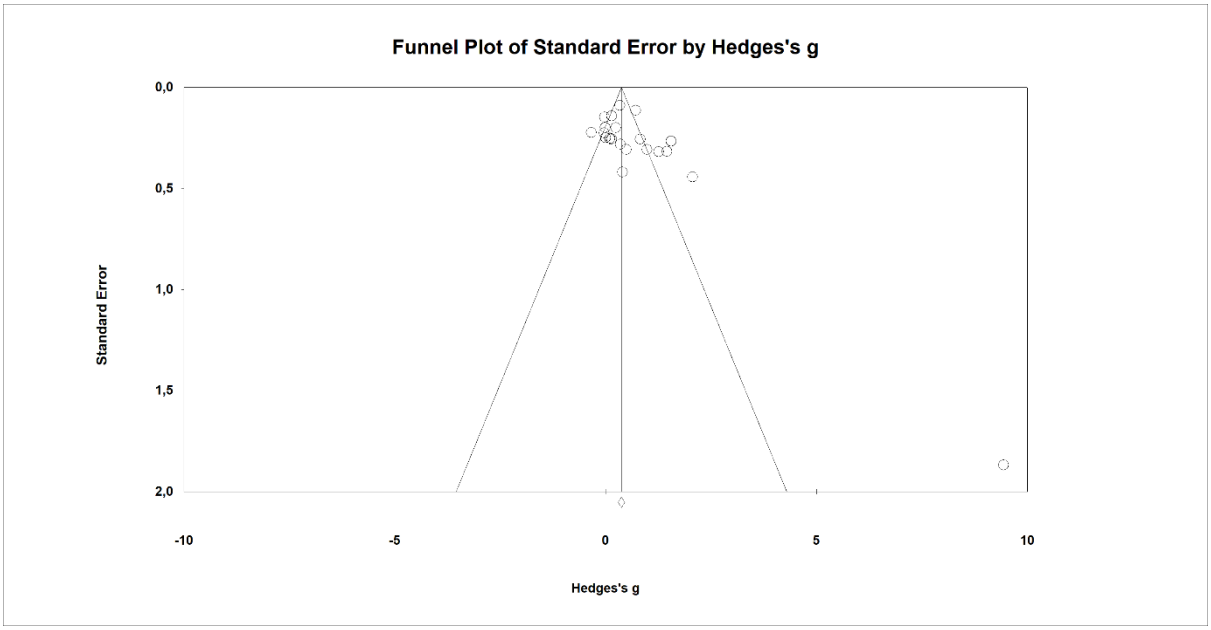

Figure 4. Funnel Plot from 22 Research Samples

Figure 4 is the plot of the research funnel. If noted, the ESS of the distributed research is not entirely proportional in the middle of the funnel plot. So, it is necessary to consider whether these results affect the publication bias. So, the Trim and Fill testing stage is carried out as illustrated in Figure 5.

Duval and Tweedie's trim and fill

		Fixed Effects			Random Effects			Q Value
	Studies Trimmed	Point Estimate	Lower Limit	Upper Limit	Point Estimate	Lower Limit	Upper Limit	
Observed values		0,37386	0,29006	0,45765	0,49343	0,26823	0,71863	126,29581
Adjusted values	2	0,35324	0,26985	0,43663	0,40871	0,16070	0,65671	165,01877

Figure 5. Trim and Fill Test

Figure 5 is the result of a trim and fill test that shows that there is no difference between the effect size and the virtual effect created according to the random effect model. Because there was no difference between the two effects, there was no publication bias in this study, and no studies were omitted or added. So, the overall effect size is calculated as 0.498, which is categorised as a minor effect unrelated to publicity bias. This value is not excessive.

Then, the results of the study were shown to answer the second question. Previously, it was shown that the estimation method is in accordance with the random effect model. This shows that the effect size of each study is heterogeneous, so category variables that affect the attachment between Based Learning and mathematical ability must be examined (Arik & Yilmaz, 2020).

Discussion

The purpose of this study is to find out how much influence the overall application of ICT-based learning has on students' mathematical abilities. Previous research related to this research was conducted by Tamur et al. (2020) in their research entitled "The Effectiveness of the Application of Mathematical Software in Indonesia; Meta-Analysis Study". The study uses the same method as this study, namely the meta-analysis method, which is a research method that combines the previous research with this study. The results of the analysis in the study explained that the overall effect size was 0.498, which was accepted as a small effect with a confidence level of 95%. The database and population used are different from those used in this study. Thus, there is a distinction between the study and this study. However, overall, the effect size is almost similar.

The results of the analysis also show that differences in education levels influence the magnitude of the effect of ICT-based learning on students' mathematical abilities. The difference could be due to different databases. Therefore, further research is needed to validate and clarify the consistency of the results.

This study also examines or analyses the differences in countries where it is a category variable. In a study that examined Based Learning on Students' Mathematical Abilities, there were sixteen studies from abroad and six other studies from Indonesia. The existence of inequalities in the average size of the effect of each category is an attraction that needs to be studied further through further research. The importance of ongoing training to effectively align the technology that teachers need (Kartal & Çınar, 2022).

Furthermore, in the stage of testing heterogeneity, a Qb value of 126.675 was obtained with a p-value of 0.000 from the determination of the estimation model. Therefore, the dissemination of the effect size was heterogeneous at $p<0.05$. The degree of variation in the size of the effect between the studies is illustrated in the I-squared value of 83.422, where the figure proves the existence of 83% of the variation in the observed effect size, illustrating the intensity of the variable tendency caused by pure heterogeneity. The existence of an I-squared value of ≥75% results in this study having high

heterogeneity (Mullen et al., 2001). Thus, this study uses an estimation-random effect model because the results of the homogeneity test are rejected.

CONCLUSION

From this meta-analysis study, 22 independent samples were analysed. According to the random effect model, ICT-based learning has a small effect on students' mathematical abilities. However, it still has a positive impact on its use. According to the data that has been analysed, it can be concluded that the ICT learning model provides a low measure of effect with a high level of confidence in the overall impact. According to the researcher, in the search for journals linked to this research, many journals have developed ICT-based learning. However, journals that have an impact on Based Learning teach Students' Mathematical Abilities in only a few journals. In addition, the findings of this research are also based on the Google Scholar database through the Publish or Perish application. In fact, there are still many related studies that cannot be downloaded because publications are required through affiliates and special payments. Thus, for further research, it is recommended that further data be collected with the aim of obtaining appropriate variables.

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