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Impact of Distance Learning on Early Childhood Development: A Meta-Analysis

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Abstract

Purpose – This study evaluates the impact of distance learning on early childhood development through a meta-analysis, focusing on the effect size of various practices, identifying potential publication biases, and conducting subgroup analyses based on electronic devices, intervention duration, and specific skills taught.

Methods/Design/Approach – A meta-analysis was conducted on 87 studies published between 2010 and 2021, selected from databases including Science Direct, Scopus, and PubMed. Comprehensive Meta-Analysis 3.0 software was employed for effect size calculations, variance analyses, and subgroup analyses, alongside publication bias tests using Funnel Scatter Plot, Clip and Fill, Rosenthal, and Orwin's Fail-Safe N methods.

Findings – The overall effect size of distance learning on early childhood development was small (0.186) with significant heterogeneity (I^2 = 87.358%). Subgroup analysis revealed that mobile-based learning had a larger effect size (0.888) compared to desktop-based learning (0.028). The duration of intervention did not significantly affect outcomes, although longer interventions showed slightly better results. Cognitive and language skills benefited most from distance learning, while other skills like self-efficacy and music showed minimal or negative effects.

Research implications – The findings suggest that mobile-based distance learning is more effective for early childhood education than desktop-based approaches. This study highlights the need for further research to refine distance learning strategies, particularly for specific skill sets, providing insights for policymakers and educators to enhance early childhood learning programs.

Originality/Value – This study offers a comprehensive analysis of distance learning's effectiveness in early childhood education, addressing gaps in the literature regarding the impact of device types and intervention durations. The findings contribute valuable insights for the development of more effective distance learning platforms for young children.

Keywords Distance learning, early childhood development, meta-analysis, mobile learning, cognitive skills.

Paper type Research paper

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1. Introduction

The rapid advancement of technology continues to have a significant impact on various aspects of life, including the field of distance education. Numerous studies have shown that technologies such as audio/video streaming, high-speed connectivity, and handheld devices have provided substantial benefits to distance education (Gu et al., 2019; Muthuprasad et al., 2021). One of the most intriguing aspects of these technological advancements is the increased capacity for interaction, collaboration, and inclusion in the learning process (Fu & Hwang, 2018; Pedro et al., 2019; Radianti et al., 2020). Technologies like real-time audio/video, teleconferencing, and screen sharing play a crucial role in education, especially when combined with an intuitive user experience and functional instructional design (Mohammadi et al., 2020).

Research on distance education has been extensively discussed by scholars. Berndt et al. (2017) explain that distance education can be delivered through various technologies such as video conferencing, teleconferencing, web-based platforms, and virtual reality. However, previous research has focused more on technical characteristics than on the educational outcomes achieved (Steed, 2009). For instance, a study compared technology-based delivery with face-to-face learning and found that both methods were comparable in terms of satisfaction and learning outcomes (Miller et al., 2008). Nevertheless, some studies report changes in practice due to educational interventions (Maloney et al., 2011; Nipp et al., 2014).

The use of virtual reality in education, as noted by Christian et al. (2021), shows an enhancement in experience, motivation, and understanding of abstract concepts. Virtual reality creates an immersive environment for interaction and effective learning. Recent studies also indicate an increased use of virtual reality in language learning, particularly through comparative experimental methods between groups of students using VR and traditional methods (Christian et al., 2021; Parmaxi, 2020). Chien et al. (2020) found that using the SVVR system for English language training with a peer assessment approach can improve performance, motivation, and critical thinking in English. Lan et al. (2016) stated that placing students in an SVVR environment positively impacts their higher-order thinking skills. Furthermore, Pinto et al. (2021) added that virtual learning with gamification strategies can effectively teach foreign languages.

Although the effectiveness of distance education is comparable to face-to-face learning (Kusmaryono & Jupriyanto, 2021), there are significant opportunities for further development of distance learning applications as many academic institutions transition to this model (Armstrong-Mensah et al., 2020; Herodotou et al., 2020). The main challenge in improving the quality of distance education is the development of content that aligns with the curriculum. Distance education will become a natural part of the learning process and eventually replace traditional teaching and learning methods (Almanar, 2020; Basilaia, 2020).

Moreover, research on distance learning in early childhood education shows significant impacts. A study by Champeaux et al. (2020) indicated that home-based learning due to the COVID-19 pandemic had a more significant negative impact on boys attending kindergarten in Italy, particularly those whose parents had lower educational levels. Increased screen time was also associated with lower learning achievement and emotional status (Cerniglia et al., 2021; McArthur et al., 2021). However, interactive distance learning methodologies appear to mitigate these negative impacts on children in Italy and France (Champeaux et al., 2020).

Research by Prabandari et al. (2018) also revealed the readiness for implementing distance learning programs in Southeast Asia, including Indonesia, Thailand, Cambodia, and Vietnam. Their findings indicate that distance learning programs are feasible and ready to be implemented in each of these countries.

Furthermore, a meta-analysis study by Allen et al. (2004) demonstrated that distance learning has advantages over traditional learning. The calculated effect sizes were heterogeneous, prompting a moderation variable analysis, although no moderation variable resulted in homogeneous effect sizes (Allen et al., 2004). Building on previous studies that have highlighted the importance of research on distance learning, this study aims to provide a specific perspective on the effectiveness of distance learning in developing early childhood skills. The study also seeks to uncover potential publication bias and conduct a subgroup analysis based on three moderating variables: the type of electronic device used, the implementation time, and the type of skills being taught. This research is essential for accurately depicting the benefits of early childhood education through distance learning.

2. Methods

This study employs the meta-analysis method, which is the quantitative analysis of empirical studies conducted on a specific topic or related field, combining studies based on predefined criteria. As described by Al Mamun et al. (2018), meta-analysis synthesizes quantitative results across studies, offering increased validity in understanding specific phenomena. In simple terms, Cohen et al. (1982) define meta-analysis as "an analysis of analyses."

In this study, meta-analysis is used to calculate the effect size of distance learning on early childhood development. We systematically searched the following databases: Science Direct, Scopus, PsychINFO, Education Resources Information Center (ERIC), Academic Search Complete, and PubMed.

The process began by defining relevant keywords: ("electronic learning" OR "online course" OR "online class" OR "e-learning" OR "virtual learning" OR "hybrid learning" OR "distance learning") AND ("adolescence" OR "preschool" OR "early childhood" OR "children") AND ("academic performance" OR "learning outcomes" OR "academic achievement").

The search yielded 1,189 studies, including journal articles, Bachelor's, Master's, and Ph.D. theses. The inclusion and exclusion criteria were then applied as follows:

Criterion 1 (Research Method): The study must be quantitative.

Criterion 2 (Time Frame): The study must have been conducted between 2010 and 2021.

Criterion 3 (Publication Type): Accepted studies included Bachelor's, Master's, and Ph.D. theses, as well as articles published in peer-reviewed journals.

Criterion 4 (Data Availability): The study must report means, standard deviations, and sample sizes for both experimental and control groups.

The reliability of the study was ensured through a structured coding process in Ms. Excel, capturing study identifiers and relevant data points for analysis.

3. Results

3.2 Study Descriptive Statistics

Based on the collected data, there are 87 studies related to the theme. Of these studies, there were 64 desktop-based studies and 23 mobile-based studies (**table 1**). The period of implementation of treatment in the analyzed studies also varied. Variations in the implementation of treatment ranged from 1 week to 1 year. To compare the level of effectiveness of this study according to the period of application, the study subgroups were grouped into three groups, i.e., "less than 3 months", "3-6 months", and "more than 6 months". Of all the studies used in this meta-analysis study, they were all published in the form of journal articles. In this meta-analysis, sub-groups were also mapped based on the

abilities taught. There are 10 mapped abilities, i.e., affective, language, self-efficacy, health, cognitive, literacy, mathematics, music, sports, and technology.

Table 1. Frequency and Percentage of Studies by Level, Type, Period, and Course

Moderator	Frequency (f)	Percentage (%)
Device Type		
Desktop Based	64	73.5632183908046
Mobile Based	23	26.436781609195403
Treatment time		
< 3 months	48	55.172413793103445
3 - 6 months	17	19.54022988505747
> 6 months	22	25.28735632183908
Course		
Affective	5	5.747126436781609
Language	35	40.229885057471265
Self-Efficacy	3	3.4482758620689653
Health	8	9.195402298850574
Cognitive	20	22.988505747126435
Literacy	2	2.2988505747126435
Mathematics	2	2.2988505747126435
Music	2	2.2988505747126435
Physical Education	2	2.2988505747126435
Technology	8	9.195402298850574

This study used Comprehensive Meta-Analysis 3.0 (CMA 3.0) to compare Effect size, variance, and subgroups. In this study, the group that received distance learning-based treatment was coded as the experimental group, and the other group that was not given treatment (traditional learning practice) was coded as the control group.

The CMA 3.0 statistical package program was used in this study to compare effect sizes, variances, and groups. In this meta-analysis, the groups given the Distance Learning treatment were coded with the experimental name group. The other group given the traditional learning treatment was coded as the control group. In this study, the positive effect size is interpreted in distance learning-based learning, while the negative effect size is interpreted in the traditional learning practice.

From the collected studies, the level of significance used is 0.05. For this reason, in this meta-analysis, the statistical significance level used is also 0.05. This meta-analysis interprets the effect size value based on the Cohen measure value interval (J. Cohen, 1988). In the Cohen interval, it is stated that 0.20-0.49 indicates a small effect, 0.50-0.79 indicates a moderate effect, and 0.80 and higher indicates a significant effect.

3.3 Publication Bias

If the published articles show positive or statistically significant results, it is higher than those that show negative or insignificant results, causing bias from the published studies. This, of course, will directly affect the meta-analysis research conducted based on the literature found (Rothstein et al., 2006). To a certain degree, publication bias can be demonstrated by the calculated value being higher than the actual and affecting the calculated mean effect size (Borenstein et al., 2009). Based on this understanding, it is essential to do a publication bias test before the meta-analysis test.

In meta-analytical research, a publication bias test can be performed with several types of analysis. This study uses 3 bias tests: Funnel Scatter Plot, Clip and Fill, Rosenthal, and Orwin's Fail-Safe N. These 3 bias tests are commonly used in meta-analysis studies (Üstün & Eryılmaz, 2014). Each of these tests will measure the possibility of publication bias.

In the funnel scatter plot, the x-axis shows the magnitude of the effect size value. The y-axis shows the standard error. From the funnel scatter plot graph, it can be seen that the distribution is relatively symmetrical around the primary effect size. However, some studies get off the funnel line. In addition, based on trim and fill calculations, it was found that no studies should be added to eliminate publication bias.

Rosenthal stated that the number of studies added to the meta-analysis study could be calculated to reset the obtained effect size to 0 (Rothstein et al., 2006). In the calculation results, if the value of fail-safe N is greater than the number of observed studies, it can be concluded that the results obtained are resistant to publication bias. Orwin also suggests that the number required to reset the effect size value to insignificant or zero can be calculated in the meta-analysis. (Rothstein et al., 2006). In this study, the Rosenthal fail-safe N value is 475. This means that 475 studies are needed with insignificant effect sizes, which would make this meta-analysis research publication biased. Based on the large number, it can be concluded that the meta-analysis research is resistant to publication bias.

3.4 Combined Findings

Based on the results of the meta-analysis test conducted using the CMA 3.0 application, it was found that the effect size value of distance learning-based learning practices on early childhood development was 0.064 with the fixed-effect model and 0.186 with the random effect model. If we refer to the homogeneity test results by referring to the Q-Value of 680.286 and the P-value of 0.000, it can be concluded that the existing data is heterogeneous. Referring to (Yildiz et al., 2015) explanation, a random effect model is used with homogeneous data results. For this reason, in this study, the effect of distance learning-based learning on early childhood development uses a random effect model. The results of the calculations in the study show that the value of the random effect that appears in this meta-analysis is 0.186. This result shows a small effect concerning the classification made by (J. Cohen, 1988). It can be seen in the funnel plot in more detail, as shown in **Figure 1**.

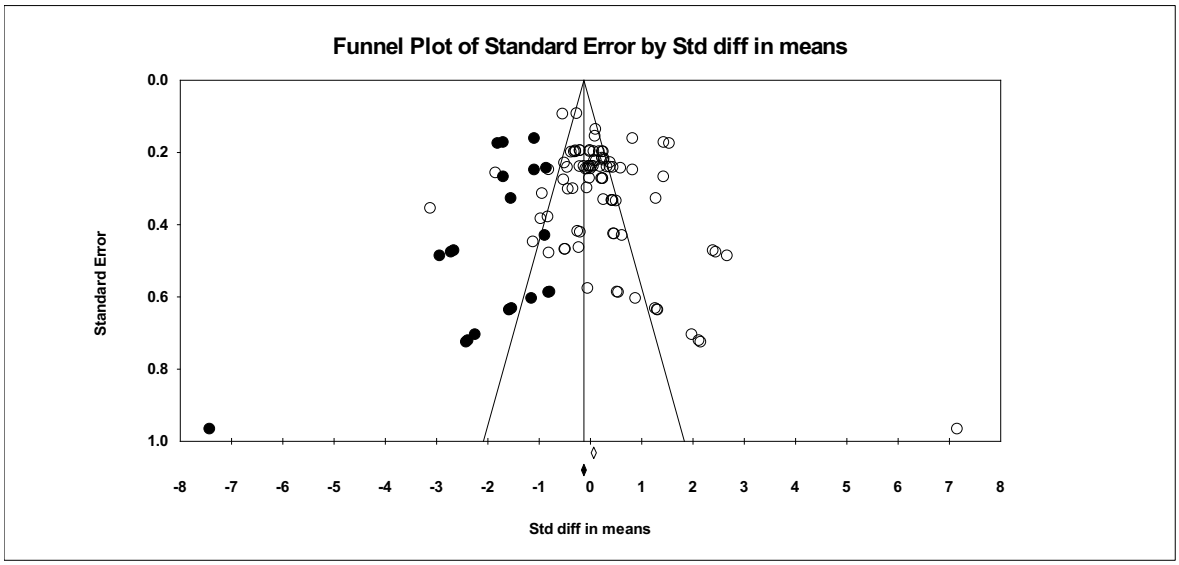

Figure 1. Funnel Scatter Plot

In addition, the I^2 value obtained is 87.358%, which is greater than 75% (**table 2**). This shows that the effect size value of the studies conducted on development has high heterogeneity (Borenstein et al., 2009). To explain this heterogeneity distribution, moderating variables are used, i.e., the type of electronic device used, the time of treatment

implementation, and the type of ability taught. The moderating variable is the variable that is considered to influence the meta-analysis results and is used in the meta-analysis to determine the level of effect. For this reason, a subgroup analysis was carried out to test the moderating variables of this study.

Table 2. The Effect Size Model of the Studies Performed in the Meta-Analysis Includes the Homogeneity Distribution Value, the Mean Effect Size, and the Confidence Interval.

Model	Effect Size and 95% confidence interval						Absence Hypothesis		Heterogeneity		
	Number of studies	Effect size	Standard error	Variance	Lower Limit	Upper limit	Z-value	p-value	Q-value	Df (Q)	I^2
Fixed Effects	87	0.064	0.026	0.001	0.013	0.115	2.450	0.014	680.2860	86	87.358
Random Effects	87	0.186	0.078	0.006	0.034	0.338	2.402	0.016			

3.5 Sub-group Analysis

Sub-groups in this study were divided into 3 parts, i.e., the type of electronic device used, the time of treatment implementation, and the type of ability being taught. First, to determine the influence of Distance Learning-based learning practices on early childhood development according to the type of electronic device used, it is classified into 2 levels, i.e., Desktop based and Mobile-based. From the meta-analysis results of the study, after dividing based on the two levels, there is an effect size value of 0.028 for desktop-based and 0.888 for mobile-based. This shows a significant difference between desktop-based and mobile-based about the effect of distance learning-based learning on early childhood development. This can be seen from the homogeneity test results, where the Q-value is 10.065, and the P-value is 0.002. Mobile-based electronic devices have higher yields than Desktop-based electronic devices.

Second, from the results of a search conducted on the collected studies, it was found that the studies carried out had different durations of time. To determine differences in distance learning-based learning practices on early childhood development based on the timing of the treatment given to students, the studies were classified into 3 groups, i.e., "less than 3 months", "3-6 months", and "more than 6 months". Based on the results of the meta-analysis conducted using the Comprehensive meta-analysis V3 application, it was found that the average effect size of each group was 0.080 for studies conducted less than 3 months, 0.318 for studies conducted between 3-6 months, and 0.363 for studies carried out for more than 6 months. This shows no significant difference between the implementation time of treatment in the distance learning-based learning on early childhood development. This can be seen from the homogeneity test results, where the Q-value is 2.635, and the P-value is 0.268. However, when viewed from each effect size, it can be seen that there is a high increase in the type of study within less than 3 months and the type of study within 3-6 months. In addition, there was also a slight increase in the type of study within 3-6 months and more than 6 months. This shows that the more time spent giving treatment, the better the effect size. However, the child's improvement tends to decrease when the treatment is given for more than 6 months.

Third, there is a mapping of the types of abilities being taught based on collected previous studies. From the mapping results, it was found that there were 10 different abilities. The ten different abilities are affective, language, self-efficacy, health, cognitive, literacy, math, music, sports, and technology. From the results of the meta-analysis, it was found that the average effect size for each ability is as follows: affective (0.202), language (0.368), Self-Efficacy (-1.352), health (-0.041), cognitive (0.440), literacy (-0.054), math (0.269), music (-0.798), sports (-0.663), and technology (0.020). They were referring to the homogeneity test results where the Q-value of 22.303 and the P-value of 0.008 indicate significant differences in the types of abilities taught in the effect of distance learning-based learning on early childhood development.

4. Discussion

This study aimed to identify experimental studies using meta-analysis methods based on distance learning theory. A total of 87 experimental studies were included in the analysis as they met the inclusion criteria. The results revealed that more than half of the studies were conducted using desktop-based experiments. Additionally, the majority of interventions were carried out over a period of less than three months, with language and cognitive skills being the most developed capabilities.

In meta-analyses, it is crucial to consider publication bias and effect size values of the studies (Schmid et al., 2020). Several methods were employed in this research to determine publication bias. Based on the results of the funnel plot, the distribution of the main effect values appeared relatively symmetrical. Furthermore, no additional studies were needed to eliminate publication bias according to the trim and fill method. The Fail-Safe N method calculation indicated that the fail-safe N value was greater than the number of studies used, suggesting that the results obtained are resistant to publication bias. Specifically, the calculation revealed that 475 insignificant studies would be required to bias the publication of this meta-analysis.

This meta-analysis concludes that distance learning practices have a positive effect on the development of early childhood skills. According to J. Cohen's classification (1988), the calculated effect size for early childhood development falls within the "small effect" interval. Therefore, it can be stated that the effectiveness of distance learning practices has a relatively small impact on the development of early childhood skills. In another study, Champeaux et al. (2020) even described that home-based learning due to the COVID-19 pandemic had a more significant negative impact on boys attending kindergarten.

This study also examined whether the effect size of distance learning practices on early childhood skill development varied based on the type of device used. The studies included in this meta-analysis were classified into two groups: desktop-based and mobile-based studies. From the effect size values for desktop-based studies, it was found that this category falls within the small effect size. Meanwhile, mobile-based studies were categorized within the large effect size. Considering the homogeneity value, there was a significant difference between desktop-based and mobile-based studies. Mobile-based studies had a higher effect in enhancing early childhood skills compared to desktop-based studies. This aligns with the research by Moro et al. (2017), which demonstrated that more cost-effective mobile-based VR is equally suitable for teaching isolated systems as more expensive desktop-based VR. Mobile-based learning also has advantages over desktop-based learning (Dalipi et al., 2017; Kaliisa et al., 2019).

Moreover, this study investigated whether there were differences in the effects of distance learning practices on early childhood skill development based on the duration of time. Distance learning for early childhood skill development, based on the duration of the intervention given to students, was classified into three groups: "less than 3 months," "3-6 months," and "more than 6 months." From the effect size perspective, it was found that

studies conducted in less than 3 months, 3-6 months, and more than 6 months all had small effect sizes. This finding was confirmed by the homogeneity values, which indicated no significant differences between the effects of distance learning practices on early childhood skill development based on duration. These results contrast with several other meta-analyses that have revealed differences in treatment duration (Karagöl & Esen, 2019; Talan, 2020; Turgut, 2017; Turgut & Turgut, 2018).

In the final subgroup analysis, a test was conducted to examine differences in the effects of distance learning practices on early childhood skill development based on the type of skill being taught. Based on the mapping performed, ten skills were discussed in this meta-analysis. These ten different skills include affective, language, self-efficacy, health, cognitive, literacy, mathematics, music, physical education, and technology. The homogeneity analysis results revealed significant differences in the types of skills taught concerning the effects of distance learning on early childhood skill development. The two highest skills with positive effect sizes were language and cognitive development. These findings contradict previous research that did not find differences in the aspects of the skills taught (Baş & Beyhan, 2019; Ergen & Kanadli, 2017).

5. Conclusion

Based on the results of the conducted meta-analysis, the effect sizes from the collected studies regarding the impact of distance learning on early childhood development indicate a small overall effect. However, the analysis of publication bias suggests that there is no significant publication bias present. This small effect size can be understood in light of the differences found in the subgroup analysis.

This research has important implications for the future enhancement of the quality of distance learning for early childhood education. The subgroup analysis revealed that mobile-based distance learning demonstrated more significant outcomes compared to desktop-based learning, which could serve as a foundation for the development of further studies. Additionally, the skills developed through distance learning in early childhood can be further explored and reproduced by referencing the latest theories on children's capabilities.

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Author contribution statement

Ahmad Syafii: Conceptualization, Methodology, Investigation, Writing - Original Draft, Writing - Review & Editing, Project Administration. **Sigit Purnama:** Formal Analysis, Resources, Data Curation, Writing - Review & Editing, Visualization.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of interest statement

No potential conflict of interest was reported by the authors.

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