

The effect of distance learning on student learning achievement: a meta-analysis

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ABSTRACT

Distance learning has been an option during the last few years due to the coronavirus disease 2019 (COVID-19) pandemic. The aim of this research is to identify the effectiveness of distance learning compared to conventional learning in terms of student learning achievement. This research is meta-analysis of random group contrast design (experiment-control) models. The data selection process refers to the inclusion criteria of year, theme, data type and data completeness. Based on these criteria, 10 articles were selected. The analysis process begins with testing the homogeneity assumption using three methods, namely τ^2 , I^2 , and Q which shows heterogeneous data so that random model selection is appropriate, testing freedom of publication bias with Egger's test and funnel plot which shows that the data collected is free from publication bias, identifying the effect size and standard error, as well as conducting moderator variable analysis which considers domain, continent, subject, education level and year variables. The results of this study show that although distance learning has a positive influence on student learning achievement, the difference is not significant when compared with conventional learning. In addition, these results can be moderated by achievement domain variables, type of subject, level of education, and year.

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1. INTRODUCTION

Several innovations to support the needs of students' learning processes have emerged in the education sector. Distance learning is one of the innovations that have emerged as a result of current technological developments [1], [2]. Distance learning is a planned teaching and learning process where the teaching process occurs in a different place from the learning process [3]. The learning and teaching process in an educational institution is not limited to the classroom [4], [5]. The learning and teaching process can be carried out flexibly using a computer or smartphone via an internet connection, either synchronously or asynchronously.

The coronavirus disease 2019 (COVID-19) pandemic has strengthened the role of distance learning. To prevent the spread of COVID-19, teaching and learning activities have been shifted to online distance learning using various platforms such as Zoom, Google Meet, learning management system (LMS), and so on. By using various media in distance learning, students can learn from anywhere without being constrained by space and time [6]. They can study at a more convenient time, location, and under more flexible settings [7]. In addition, teachers' teaching sessions can be recorded and archived so that students create flexible learning plans [8]. More importantly, the distance learning system can be modified by students so that it suits each student's needs [9]–[11].

Despite the potential benefits that distance learning offers to students, the existing body of research on the impact of distance learning on student learning attainment has shown inconsistent findings. Multiple studies have indicated that distant learning exerts a substantial impact on academic attainment. According to a recent study conducted by Zen *et al.* [12], it has been found that college students who engage in problem-based online learning (PBOL) exhibit superior competencies and engagement in the context of entrepreneurship courses compared to their counterparts in traditional classroom settings. According to previous research conducted by Jen *et al.* [13], it has been shown that the implementation of video-based distance learning has proven to be effective in alleviating learning anxiety and enhancing nursing staff's understanding of COVID-19 protection measures. Additionally, this approach has demonstrated positive outcomes in terms of improving learning outcomes, critical thinking abilities, and self-efficacy among students. By contrast, a number of studies have posited that traditional learning methods are superior to distant learning, while others argue that there is negligible disparity between the two approaches. According to a study conducted by Chen *et al.* [14], it was shown that university students who engaged in traditional face-to-face problem-based cooperative learning exhibited greater scores in programming learning achievement compared to students who participated in online learning. In recent studies conducted by Hwang *et al.* [15], Ralević *et al.* [16], and Zhang and Yu [17], it has been observed that there exists no statistically significant disparity in terms of elementary student and junior high student learning achievement between distant learning and conventional learning approaches.

In recent years, a plethora of scholarly research has been conducted about remote learning or online learning. Several studies have been conducted to evaluate the efficacy of remote learning or online learning, including systematic reviews and meta-analyses [8], [18]–[22]. Multiple meta-analytic studies have been conducted to examine and compare the learning outcomes associated with distance learning and traditional classroom-based instruction. In a study conducted by Gegenfurtner and Ebner [19], the effectiveness of webinars, which are a form of synchronous online learning, was examined in both college students and professional training participants. The researchers compared the learning outcomes of webinars with those of conventional learning and asynchronous online learning. The findings indicate that webinars exhibit a modestly higher level of effectiveness compared to traditional learning methods, albeit with a marginal disparity. An additional illustration may be found in the study conducted by Müller and Mildemberger [21], whereby they investigated the impact of remote learning (specifically blended learning) in relation to traditional learning, with a focus on learning outcomes. The findings indicate that the implementation of blended learning can yield learning outcomes comparable to those of traditional learning, albeit with a marginal disparity.

Although the aforementioned meta-analysis research has been conducted to examine the effects of distance learning on learning achievement, the majority of these meta-analysis studies have constrained their literature search only to higher education and professional training levels [8], [18]–[22]. The prevalence and utilization of distance learning have experienced a notable surge, encompassing not only higher education and professional development but also primary and secondary education (ranging from primary school to high school). This trend has been particularly pronounced following the onset of the COVID-19 pandemic, as evidenced by previous studies [23], [24]. According to Zeng and Luo [8], the inclusion of primary and secondary education levels in literature searches can yield a more comprehensive understanding of the efficacy of distance learning. In addition, expanding the scope of the search would yield further empirical information that can effectively substantiate the claims made in favor of instructors.

There are some research's which reported the effect of distant education to learning achievement. Most of the studies reported the effect for higher [11], [13], [16], [18] even professional [12] by having different kind of learning method and media used, but only few studies have been found regarding the effects of distance learning on elementary students. It has not figured out the effect of distant education to students' achievement comprehensively. Therefore, this study considers the broader inclusion criteria like respondents' characteristic. This study aimed to proof the stronger effects of distance learning than conventional learning, and the effects subject to variation based on the presence of a moderator variable. Particularly within the realms of education and achievement domains.

2. METHOD

The present study employed a quantitative research design utilizing the group contrast meta-analysis method. The primary objective of group contrast meta-analysis is to get a comprehensive and conclusive understanding from a collection of prior studies that share a common thematic focus [25], [26]. The research conducted with this particular model involves the collection of data from pre-existing research publications, which were subsequently subjected to statistical analysis in order to derive comprehensive results on a worldwide scale [27]. The central focus of this study pertains to the impact of remote learning on students' academic performance.

As elucidated earlier, the data utilized in this study was derived from research completed by prior scholars. The research papers that were searched employed pertinent keywords related to the topics of distant learning and student learning achievement. The terms encompass "online learning", "distance learning", "distance course", "learning achievement", "student achievement", or a combination thereof. The articles that have been discovered are subsequently chosen based on the seven criteria outlined in Table 1. The study does not include articles that fail to meet the seven inclusion criteria.

A total of 1,680 article documents pertaining to the impact of remote learning on student learning attainment for the period of 2018-2022 were identified through keyword searches. The keywords used are "online learning", "distance learning", "distance course", "learning achievement", "student achievement", or a combination of these keywords. Figure 1 depicts the method of gathering and choosing publications for this research. However, a total of 10 papers were identified that satisfied the specified inclusion criteria and were subsequently subjected to analysis. Within the collection of 10 publications, a subset of them encompasses intricate research issues, hence facilitating the analysis of several studies. An investigation conducted by Hwang *et al.* [15] examined the impact of distance learning on three dimensions of student learning outcomes, specifically cognitive abilities, motivation, and self-efficacy. A further illustration of scholarly inquiry is the investigation undertaken by Zen *et al.* [12], wherein they examined the impact of problem based online learning (PBOL) on the acquisition of conceptual understanding, creativity, leadership skills, willingness to take risks, and entrepreneurial aptitude. Hence, present study examines a total of 36 datasets derived from a curated selection of 10 scholarly journals.

The present study employed a random effect model to provide a comprehensive summary of research findings that may be extrapolated to a broader population. For data to be suitable for analysis using a random effect model, it is necessary for the data to satisfy the criterion of heterogeneity. The heterogeneity criteria for this research are demonstrated by the utilization of three methodologies, specifically τ^2 , I^2 dan Q . Three strategies are employed to ensure the precision of decisions in order to establish heterogeneity. According to Higgins *et al.* in 2020 [28], data is considered to satisfy the criterion of heterogeneity when the I^2 statistic reaches a minimum threshold of 30%, τ^2 is higher than 0 [29] and p-value of $Q < 0.05$ [30].

The present study employs a contrast group meta-analysis design to examine potential disparities in student achievement between distance learning and conventional learning. The collected data exhibits diverse intervals, so rendering the straightforward estimation of the effect size from the disparity between the means of the treatment and control groups unattainable. Hence, it is necessary to normalize the sample mean or effect size. The data analysis procedure was conducted utilizing the R programming language, employing the meta package [31] and metafor [32].

Following a comprehensive meta-analysis, the subsequent step involves conducting a meta-analysis incorporating moderator variables. These moderator variables are carefully chosen to offer a more detailed insight into the meta-analysis findings. Table 2 provides a comprehensive list of the moderator variables employed in this study. An analysis of variance (ANOVA)-like model was utilized to scrutinize these moderator variables, revealing their respective positions in relation to the effect magnitude. The approach to infer interaction in the presence of moderating variables entails examining the p-value associated with the test. A p-value below 0.05 indicates a significant difference in interaction within the moderation variable.

Table 1. Aspects and criteria for data collection

Aspect	Inclusion	Exclusion
Time	2018 to 2022	-
Language	English	-
Data Type	Quantitative	-
Data	1. Has mean score for each group 2. Has n (sample size) for each group	Does not have one or both conditions
Theme	The effect of distance learning on student achievement	-
Analysis data	Group Contrast/Experiment	-
Database	Scopus, Directory of Open Access Journals (DOAJ), Web of Science (WoS)	-

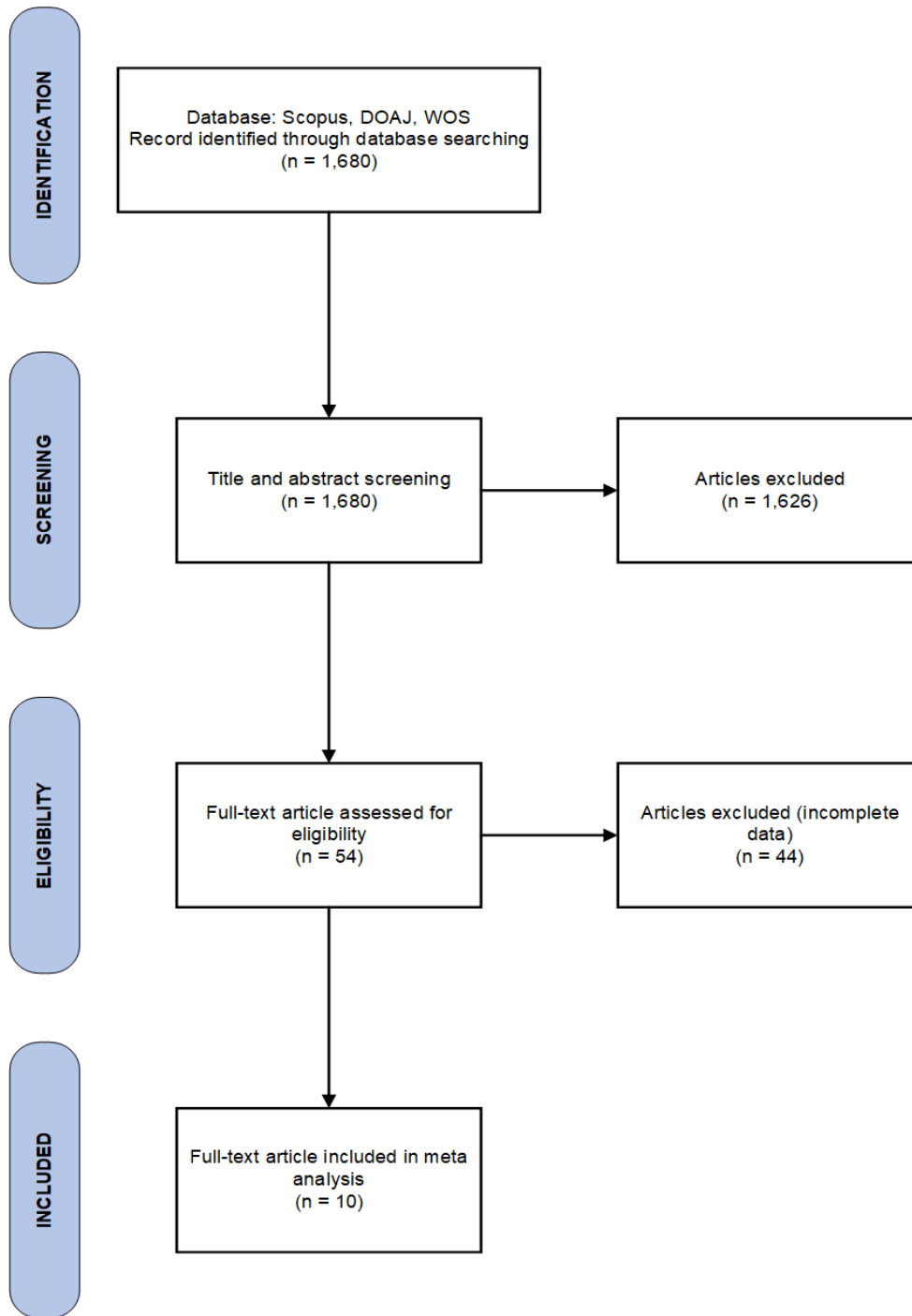


Figure 1. Prisma flowchart for literature searching

Table 2. Moderator variable

Moderator variable	Identified categories	Frequency of studies	Moderator variable	Identified categories	Frequency of studies
Domain	Cognitive	18	Level	Elementary	12
	Skill	6		High school	8
	Attitude	10		University	4
Continent	Asia	31	Year	2019	12
	Europe	3		2020	1
Subject	Social	7		2021	8
	Math	11		2022	13
	Science	16			

3. RESULTS AND DISCUSSION

3.1. Describing article

34 research findings were gathered for this study through the examination of 10 scholarly publications. The distance learning group consisted of 1,636 individuals, whereas the control group had 1,576 participants, resulting in a total sample size of 3,212 participants. Based on a sample of 34 study data, the data may be classified into three categories: university level (N=14), high school (N=8), and elementary school (N=12). The predominant source of research data is derived from the Asian continent, accounting for a total of 31 data points, while the remaining data points, totaling 3, originate from Europe. In the realm of assessing learning outcomes, multiple studies have conducted measurements across various domains. Specifically, these domains include the cognitive domain (N=18), the skills domain (N=6), and the attitude domain (N=10).

3.2. Publication bias

Publication bias in meta-analysis is the condition where the selected research literature does not accurately represent the entire population of studies in the meta-analysis [30]. Evidence of publication bias was assessed visually and statistically. A funnel plot can be used to visually represent publishing testing. Based on the funnel plot in Figure 2, it is clear that this study did not encounter publication bias. This is because the data points in the funnel plot are symmetrically distributed. Statistically, publication identification can be proven by the file-safe N method and Egger's test. The data criterion is said to be free from publication bias for the file-safe N method when $N > 5K + 10$ (K is the number of studies). Analysis using Egger's test was carried out to estimate an asymmetric funnel plot. The criterion is that the funnel plot is not asymmetrical by looking at the p-value > 0.05 . The analysis results for file-safe N showed that the data were free from publication bias ($N = 490$ (95% Confidence interval (CI)) > 185). Apart from that, the results of Egger's test also concluded that the funnel plot in Figure 1 was confirmed to be symmetrical ($t(33) = 0.91$, $p = 0.37$). Thus, it can be concluded that this research data confirmed that there is no publication bias problem.

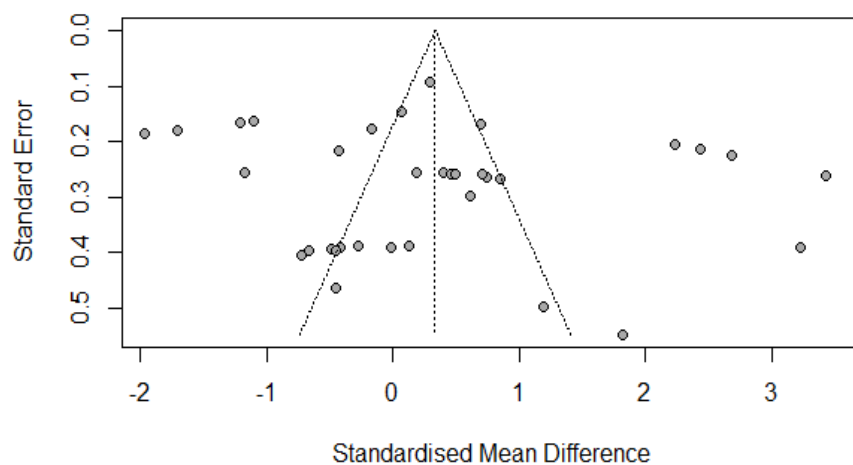


Figure 2. Funnel plot indicating no publication bias

3.3. Summary effect size

The forest plot of the entire research data comparing distance learning with conventional learning can be seen in Figure 3. The results of the weighted average using the random effect model show that the average effect size is positive but small and not statistically significant ($g = 0.325$, $p = 0.153$), with a 95% confidence interval between -0.12 to 0.77 . These results show that distance learning does not have a statistically significant effect on student learning achievement compared to conventional learning. The homogeneity test results showed a statistically significant Q value ($Q = 1024.73$ ($df = 33$, $p < .001$)). Therefore, we can reject the null hypothesis which states that the true effect size is the same across studies. The variance of the true effect size was $\tau^2 = 1.67$ (95% CI [1.049; 2.93]) which accounted for most of the observed variation ($I^2 = 96.8\%$, 95% CI [96.1; 97.3]). According to Higgins *et al.* [28] I^2 greater than 30% indicates that heterogeneity occurs in the data. A high I^2 value indicates that additional analysis is needed, namely moderator analysis to explore factors that can explain the large variance in the data [20].

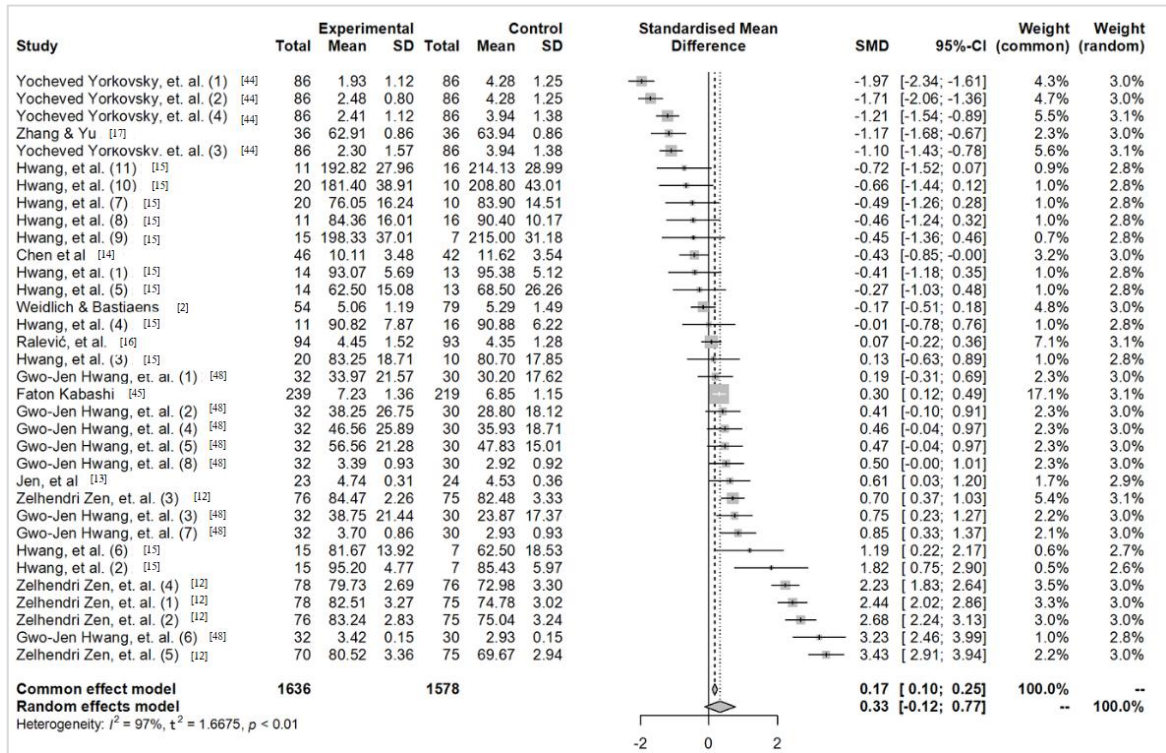


Figure 3. Forest plot of effect size of the studies included (k=34)

3.4. Moderator variable analysis

The outcomes of the heterogeneity test conducted on the estimation of the actual effect size indicate the presence of variations in the true effect size within the dataset analyzed in this meta-analysis. A subgroup analysis was conducted to examine potential variations in the effect magnitude based on the assessed domain, continent, subject, level of education, and year. The subgroup analysis findings are visually presented in Figure 4, specifically in the forest plot.

The impact of distant learning is observed across three areas of learning achievement within the subgroup, specifically cognitive, skills, and attitude. The subgroup analysis revealed a significant difference in effect size among the domain subgroups ($Q = 5.98$, $df = 2$, $p = 0.05$). Put simply, the impact of remote learning differs based on the specific domain of learning achievement that is being assessed. The forest plot pertaining to the subgroup domain indicates a substantial influence of distance learning on the skill domain ($g = 1.54$, 95% CI [0.36, 2.71]).

The subject variable demonstrates a significant difference in effect size among the subject subgroup ($Q = 7.00$, $df = 2$, $p = 0.03$). This observation suggests that certain disciplines exhibit varying reactions towards the use of distance learning. The various reactions elicit diverse learning results among pupils. The findings of this study indicate that individuals within the social domain exhibit a substantial and favorable effect size ($g = 1.45$, 95% CI [0.20, 2.69]) when engaging in distance education. Conversely, it was observed that students in the science discipline exhibited superior performance when exposed to traditional instructional methods, despite the effect size being minimal ($g = -0.21$, 95% CI [-0.57, 0.15]).

The examination of moderator variables within subgroups based on educational level revealed a statistically significant variation in effect size for each level of education ($Q = 5.97$, $df = 2$, $p = 0.05$) in relation to remote learning. This implies that the impact of distant learning on enhancing student academic performance varies across different educational levels. The findings of the analysis indicate that the implementation of remote learning at the secondary school level yields a wide range of effects, varying from little to substantial ($g = 0.83$, 95% CI [0.20, 1.46]). The analysis in Figure 3 reveals that the year factor is a statistically significant variable in the diverse impacts of distance learning on learning attainment ($Q = 11.33$, $df = 3$, $p = 0.01$). The effect size magnitude exhibits variability contingent upon the year factor, primarily attributable to the global COVID-19 pandemic, which has significantly altered the educational landscape worldwide.

By adding inclusion criteria (respondents' characteristics), the data obtained in this meta-analysis is more comprehensive. The effects of distance learning were not only reported to be difference for secondary school students, but also students in social and science groups. Students in the social group reported an

increase during distance learning, in more detail, the remainder in the science group experienced an increase in the skills domain. Furthermore, the effects of distance learning were reported differently in different years. Thus, this analysis can add detailed information needed for further studies.

3.5. Discussion

Pandemic outbreak has changed several aspects in education. The face-to-face learning cannot be applied for months then there should be an adjustment. One of the adjustments is virtual laboratory. Virtual laboratory had been applied to bachelor's in electrical and electronic engineering in Malaysia [33], also, the use of learning management system (LMS), which allow both teacher and students to be able to take a study everywhere [34]. Study suggested that organizational readiness-technical infrastructure and support, flexible structures that facilitate decision-making and empower instructors, the availability of informal communication channels, and faculty members' digital skill development [35] should be given more attention for successful distance learning.

The primary objective of this meta-analysis study is to offer a comprehensive synthesis of existing data pertaining to the impact of remote learning on enhancing student learning outcomes in comparison to traditional forms of instruction. Furthermore, this study also examines if the effects of distant learning differ according to the domain of learning success, continent, discipline, educational level, and year. The utilization of a random effect model in this study reveals that the collective average impact size is both positive and tiny, indicating a slight advantage for distance learning. Nevertheless, the observed results do not exhibit statistical significance. This implies that while distance learning has a favorable impact on student learning outcomes, there is no statistically significant distinction in the effects of distance learning and traditional learning on academic achievement. In other words, distance learning does not exhibit superior efficacy compared to conventional learning in enhancing student learning achievement. The present discovery contradicts the outcomes of prior studies conducted by [20], [36], [37], which concluded that distant learning is superior to traditional learning in enhancing academic performance. Nevertheless, the considerable diversity observed in the impact size data within this study provides more support for the utilization of the random effect model. The presence of heterogeneity in the data supports the need for doing moderator analyses to investigate the elements that contribute to variability. Such analyses can offer valuable insights to educators regarding the factors that influence the successful implementation of distant learning.

The findings of this meta-analysis study indicate that the impact of distant learning on student learning outcomes, in comparison to traditional learning, is contingent upon various parameters including the cognitive domain, the content area, the educational level, and the temporal context. Distance learning has a substantial impact on student learning accomplishment within the domain of abilities, particularly when applied to the skills domain. This finding suggests that distant learning exhibits a more pronounced influence on learning accomplishment within the skills domain when compared to the cognitive and attitude domains. The learning's policy gives important role to it. Skills can be assessed by using hybrid method, students only come in small number to do the skills lab then present the result online [38]. Learning environment can give positive impact to students' achievement. In the early outbreak, students reported positive feedback to online learning, thus it can affect to their achievement [39], [40].

This finding contradicts the findings of earlier studies [20], e.g., Doo and Zhu [41] that reported superior learning achievement in the cognitive and attitudinal domains compared to other domains in the context of remote learning. One potential explanation lies within the realm of skills acquisition, where the mastery of a particular talent may be achieved by the active engagement of students in deliberate practice within diverse environments or contexts. According to Zeng and Luo [8], distance learning provides students with the ability to record instructional sessions and save them for future reference, enabling them to revisit the material in case they encounter challenges during the learning process. This feature of distance learning significantly impacts the whole learning experience.

The potential impact of distant learning on academic achievement may be influenced by the specific attributes of the instructional content provided during the learning experience also the materials medium used in the class [42]. The findings of this study indicate that remote learning significantly influences students' academic performance in non-science, technology, engineering, and mathematics (STEM) topics, particularly those related to social sciences. The findings of this study diverge from prior research conducted by Müller and Mildenerger [21], Thongsri *et al.* [43], Yorkovsky and Levenberg [44], and Kabashi *et al.* [45]. These previous studies posited that the influence of online learning on student learning outcomes in STEM disciplines, specifically mathematics and science, was either superior or equivalent to student learning outcomes in non-STEM subjects. One contributing factor to this phenomenon is the extent of students' prior exposure to technology prior to engaging in online learning. According to Das and Bhattacharyya [46], more exposure to technology, specifically computer usage and internet access, might enhance students' proficiency and familiarity with digital technology. Another study reported that technical support from the teacher

influence students' perception in distance learning [47], [48]. This, in turn, may contribute to improved academic performance in the context of remote learning.

The meta-analysis results for education level reveal an intriguing observation. The findings of the moderator analysis indicate that the degree of education serves as a moderator variable, amplifying the impact of distant learning. Moreover, the findings of meta-analytic research indicate that remote learning exerts a stronger and more favorable impact on students' academic attainment in high school settings as opposed to university settings. One plausible explanation for this phenomenon is that upper secondary students, who have been exposed to technological gadgets such as computers, smartphones, and the internet from an early age, exhibit a preference for distant learning [49]. Nevertheless, it is imperative to exercise caution when interpreting these findings, as they are derived solely from a single research article.

The variable of the year can play a crucial role as a moderating factor influencing the impact of distant learning on student achievement. Our study's findings suggest that the effect of remote learning on student academic performance is dependent on the specific academic year under consideration. In the periods leading up to and during the early stages of the COVID-19 pandemic, the introduction of remote learning exhibited a negative impact on student academic performance, though with a relatively modest to moderate effect size. It is important to note that during this timeframe, distance learning had not yet become the predominant pedagogical approach used by educators for in-person classroom instruction. As highlighted by Järvelä and Rosé [50], many members of the teaching faculty faced challenges due to a lack of preparedness and training in effectively facilitating remote learning through online platforms, primarily attributed to the disruptive nature of the COVID-19 pandemic. Moreover, various obstacles were encountered in the initial stages of the epidemic concerning the distant learning process, including difficulties with computer proficiency, insufficient internet connectivity, and other related issues. According to Tomczyk and Walker [51], the implementation of distant learning has been observed to negatively impact students' academic performance. University students, at first, feels comfortable with distance learning at least for the first six month [8], but, for almost a year, they pretend to go back to traditional learning when they can meet friends, going to library and others [52]. This insight aligns with our findings, emphasizing the nuanced relationship between the academic year, the adoption of remote learning, and its subsequent influence on student achievement.

Previous study, a systematic review of online teaching and learning, showed the limitation about broader characteristic of the sample also the quality of articles [53]. This study has been filled the limitation gap of that study. The broader characteristic, gender, learning materials, and others, have been considered in this study. Additionally, there is need to improve learning content to be taught in online learning [54], also the needs of fun virtual activities [55] which can improve their motivation then it can also increase students' achievement. This study explored a comprehensive result about the effect of distance learning to students' achievement. However, further studies may be needed to confirm its significant effect to broader characteristic, especially in skills domain and the material content.

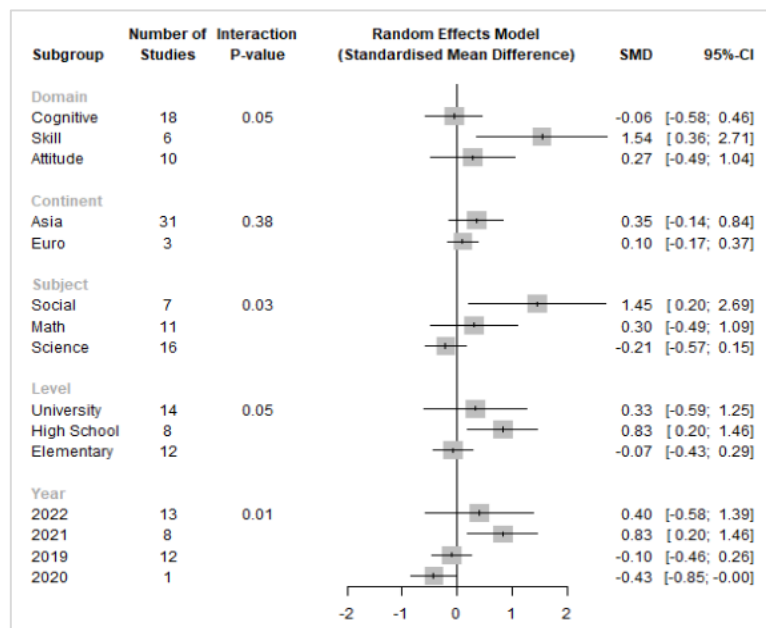


Figure 4. Forest plot based on moderator

4. CONCLUSION

Our findings found that compared to traditional classroom-based learning, distant learning has a more favorable effect on students' academic achievement. However, it is necessary to take into account the influence within the relevant context, which comprises elements like the particular learning achievement domain (cognitive, skill, or attitude), the topic type (social, mathematical, or scientific), the educational level (university, middle school, or elementary school), and the particular year being studied.




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



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