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Evaluating the effectiveness of the blended learning station rotation model: A meta-analysis of student learning outcomes

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ABSTRACT

This paper is analyzing the effect of the blended learning station rotation model on students' learning outcomes through a meta-analytic approach. The background of this research stems from the increasing use of digital technology in education, particularly after the COVID-19 pandemic, which encouraged teachers to integrate face-to-face and online learning into a unified instructional strategy. The station rotation model is considered adequate as it offers flexibility in learning time, facilitates differentiated learning, and enhances interaction between teachers and students. However, previous studies have shown varying levels of effectiveness, necessitating a comprehensive synthesis to gain an overall understanding of its impact on learning outcomes. This study employs the meta-analysis method following the PRISMA, which include the stages of identification, screening, eligibility, and inclusion. Sources obtained from indexed international journal articles, with inclusion. The results revealed that the station rotation model had a positive and significant effect on students' learning outcomes, with a moderate to high category of influence. Furthermore, moderators such as educational level, subject matter, duration of intervention, and research location were found to affect the magnitude of its impact. This study reaffirms that implementing the station rotation model can be an effective learning strategy to improve learning outcomes, particularly when integrated with adaptive instructional design and relevant digital media. There are expected to serve as a reference for educators, curriculum developers, and policymakers in optimizing the application of the blended learning model, specifically the station rotation type, at various educational levels. Future researchers are encouraged to expand the scope of inquiry to include non-cognitive variables such as motivation, learning engagement, and 21st-century skills, thereby providing a more comprehensive picture of the model's effectiveness.

INTRODUCTION

The rapid development of information technology in the past decade, coupled with the acceleration of technology adoption during the COVID-19 pandemic, has brought fundamental changes in the world of education. Now, the application of digital learning models, including blended learning, is no longer just an emergency solution, but part of the education transformation strategy in the digital era. The integration of information and communication technology (ICT) in education is now a strategic component of long-term development, aligning with the direction of the Education 4.0 policy and the Merdeka Learning initiative, which encourages the transformation of education models to meet the demands of the digital era. This paradigm emphasizes the use of technology to create a more autonomous, innovative, and oriented learning environment that improves educational outcomes (Irhamsyah, 2023; Santosa, 2022). In the era of Education 4.0, the focus of education extends beyond academic achievement to encompass the development of 21st-century competencies, including high-order thinking skills (HOTS), collaboration, communication, and digital literacy. Framework for 21st Century Learning, developed by (Battelle for Kids, 2019) emphasizing the importance of these skills as the core of modern learning. However, the implementation of digital learning in Indonesia still faces challenges, including infrastructure gaps, unequal internet access, and variations in human resource readiness across regions. The (Kemendikbudristek, 2023) has highlighted the importance of digital transformation in the education system to address these challenges and improve the quality of learning nationwide. Therefore, the selection of models that blend learning, which are flexible, adaptive, and tailored to national conditions, such as Rotation Station, becomes highly relevant to study in more depth.

One of the models widely applied in supporting digital-based learning processes is blended learning, which combines online and face-to-face learning (Astuti & Febrian, 2019; Siripongdee et al., 2020). In general, blended learning integrates face-to-face learning with online learning, where some materials and activities are conducted online, while others are still delivered directly in the classroom (Amelia, 2020; Bouilheres et al., 2020; Hrastinski, 2019). This model is considered effective in accommodating a wide range of student learning styles and improving the flexibility and quality of the learning experience (Graham et al., 2013). Type blended learning offers a wide range of benefits. In terms of flexibility, blended learning enables learning to occur anywhere and at any time, tailored to the individual needs of students (Kumar et al., 2021; Picciano, 2019). This model can also improve interaction between students, teachers, and learning materials, and encourage active engagement (Garrison & Kanuka, 2004; Picciano, 2019). Students generally report a more positive learning experience, especially in terms of flexibility, confidence, and online learning experience. Moreover, blended learning provides opportunities for teachers to conduct more individualized learning, for example, by monitoring students' online learning behaviors (Xu et al., 2021). In general, learning outcomes in blended learning are equivalent to those in traditional learning, although students still tend to prefer face-to-face sessions (Monk et al., 2020).

However, the implementation of blended learning also presents several challenges. Its success is greatly influenced by the readiness of infrastructure, institutional support, and adequate training for lecturers or teachers. Additionally, continuous evaluation is necessary to ensure quality and impact on all stakeholders (Moskal et al., 2013). Not all students experience the same benefits, so the application of blended learning requires an adaptive approach to accommodate differences in learning styles and experiences (Bouilheres et al., 2020).

Among the various variants of blended learning models, the Rotation Station approach is gaining increasing attention in contemporary educational literature. This model enables students to rotate between various learning stations, including face-to-face sessions, online learning, and self-paced activities, thereby accommodating different learning styles and infrastructure conditions (Rahmani & Zitouni, 2022; Staker & Horn, 2012). The flexibility and adaptability of this model are highly relevant to the educational context in Indonesia, which has diverse geographical conditions and varying levels of technological readiness. Moreover, Rotation Station is efficacious in improving students' academic achievement and learning habits, with higher results compared to other blended learning methods, such as the flipped classroom (Yoade & Asaaju, 2024). The implementation of Rotation Station-based project-based learning also significantly improves the critical thinking skills and mathematical intuition of junior high school students (Sari et al., 2025; Tayyeh & Hassan, 2024). Other advantages offered include the ability to support personalised learning, allowing teachers to provide customized support tailored to students' needs, and accommodating different learning styles (Mahalli et al., 2019; Yukhymenko et al., 2024). Furthermore, Rotation Station can increase student involvement, motivation, and interest in learning, especially when combined with gamification elements (Abdullah et al., 2023; Xiangze & Abdullah, 2023). However, the success of implementing this model is greatly influenced by the readiness of teachers in managing learning stations, digital competencies, and the selection of appropriate online platforms (Yukhymenko et al., 2024). Another challenge to consider is the management of group work at certain stations, which requires an effective mentoring and collaboration strategy (Seitova & Khalmatova, 2025). With all these advantages and challenges, Rotation Station is one of the variants of blended learning which shows significant potential in improving achievement, critical thinking skills, and student motivation and engagement, especially in the context of diverse Indonesian education, when supported by teacher readiness and adequate infrastructure.

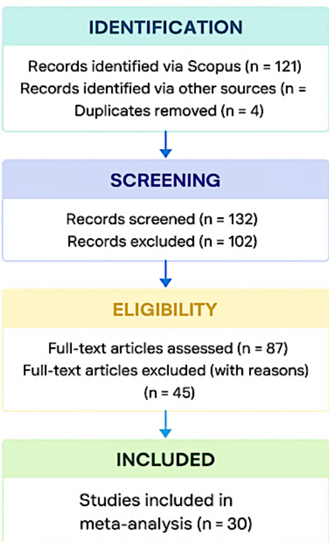
Research on model effectiveness, blended learning type, and Rotation Station Student learning outcomes shows mixed results, although many studies report the positive contribution of this model to improved learning outcomes. Several studies have recorded improvements in aspects of academic achievement, study habits, and mathematical critical thinking skills (Ayob et al., 2020; Sari et al., 2025; Tayyeh & Hassan, 2024; Yoade & Asaaju, 2024). Additionally, this model is considered effective in developing mathematical intuition and enhancing learning outcomes across various subjects (Sari et al., 2025; Tayyeh & Hassan, 2024). In terms of student motivation and engagement, Rotation Station, particularly when combined with gamification, has been shown to increase interest and active participation in learning, both online and offline (Xiangze & Abdullah, 2023). The model also supports personalized learning, enabling teachers to provide more individualized support tailored to students' needs (Yukhymenko et al., 2024). However, not all studies show significant advantages of the Rotation Station compared to other model blended learning models, such as the flipped classroom or traditional learning methods (Seitova & Khalmatova, 2025; Yoade & Asaaju, 2024). Some studies have found that student learning outcomes and motivation in specific contexts do not show meaningful differences. These differences in results are influenced by various contextual factors, including education levels, teacher readiness, availability of infrastructure, and implementation approaches applied in each institution (Seitova & Khalmatova, 2025; Yoade & Asaaju, 2024). In addition, a systematic meta-analysis study that specifically evaluates the effectiveness of the Rotation Station is still minimal, both at the international and national levels. Most meta-analyses of blended learning are still general and have not explicitly distinguished submodels, such as Rotation Station (Ayob et al., 2020; Yukhymenko et al., 2024). In fact, given the geographical characteristics and infrastructure readiness diversity in Indonesia, the study is more focused and specific to the Rotation Station model. It is indispensable to produce a more comprehensive understanding. At the elementary school level, Rotation Station improve HOTS, problem-solving, and student creativity (Christina et al., 2019; Truitt & Ku, 2018). At the junior high school/high school level, this model is efficacious in improving academic achievement, study habits, as well as critical thinking skills and mathematical intuition (Sari et al., 2025; Tayyeh & Hassan, 2024; Yoade & Asaaju, 2024). Meanwhile, at the higher education level, Rotation Station was assessed positively for its individualisation of learning, digital competency development, and learning satisfaction (Lee, 2025; Yukhymenko et al., 2024), although it requires higher digital readiness from lecturers (Lee, 2025) To date, no meta-analysis has been found that explicitly compares the effectiveness of Rotation Station between levels of education (Ayob et al., 2020), and existing research still focuses on one level, making cross-level comparisons difficult to do comprehensively (Christina et al., 2019; Lee, 2025; Sari et al., 2025; Truitt & Ku, 2018; Yoade & Asaaju, 2024). Therefore, a study that examines explicitly differences in effectiveness between levels is needed to provide an empirical basis for the development of a more targeted implementation strategy.

Through this preliminary study, the researcher found that, given the various research findings related to the effectiveness of the station rotation model in learning, it is essential to conduct a systematic examination of these findings within a meta-analysis framework. This meta-analysis study aims to provide a combined effect value from various previous studies, thereby obtaining a more comprehensive and conclusive picture of the effectiveness of station rotation on student learning outcomes. This study focuses on independent variables, namely station-rotation-based learning, and dependent variables, namely student learning outcomes. In addition, this study also examines the level of education as a moderator variable to determine how the effectiveness of this model varies at different levels of education. The results of this research are expected to make a theoretical contribution to the development of blended learning studies, as well as provide a strong empirical foundation for the development of policies and strategies for implementing blended learning, particularly station rotation, in support of the transformation of digital education in Indonesia.

METHOD

This research is a type of meta-analysis research (Retnawati et al., 2018). Meta-analysis is a quantitative statistical method for compiling and analyzing descriptive data from a variety of relevant published and unpublished research results that explore and test similar research problems and hypotheses (Glass, 1976). The stages of meta-analysis consist of (1) formulating problems, (2) searching the literature, (3) gathering information and findings from individual studies, (4) evaluating the quality of studies, (5) analyzing and interpreting the results of the study, and (6) interpreting the results or evidence (Borenstein et al., 2021). In this meta-analysis, data sources were obtained from all research artefacts that discussed the influence of the blended learning model station rotation on student learning outcomes. The research population comprises all studies that address the topic and are indexed in reputable scientific databases, including Scopus, as well as other relevant publication sources. The research sample consists of artefacts that meet the established inclusion and exclusion criteria, ensuring that only relevant research that meets quality standards is analyzed. The data collected in this study are research artefacts that discuss the influence of the blended learning model station rotation on student learning outcomes. From each artefact, the statistical data used in the calculation is recorded as the effect size. The central database used is Scopus. The selection of Scopus is based on the consideration that it is a reputable international indexing institution recognized by the Ministry of Education and Culture (Lukman et al., 2020) and has a broad scope of indexing, covering the latest research. The accessibility factor is also a consideration in the selection. The following is the meta-analysis procedure described through the PRISMA diagram as a step in performing the analysis described by Figure 1.

Figure 1. PRISMA flow diagram



Articles that match the requirements are included in the analysis database, while those that do not match are excluded. The inclusion/exclusion criteria: 1) The article examines the impact of the blended learning model's station rotation on student learning outcomes; 2) quantitative research; 3) presents experimental research, involving at least one control group and one experimental group; 4) published within the last 10 years (2015–2025); 5) indexed by Scopus; 6) contains the statistical data necessary to calculate the effect size, including the mean, standard deviation, sample size, F-value, t-value, and p-value. With the Group Contrast, the study analyzed the difference in average student learning outcomes between the groups that received the treatment (blended learning type Rotation Station) and the control groups that did not receive the treatment. In this study, the Random Effect. Because the studies analyzed come from various contexts, student characteristics, and variations in the application of blended learning type Rotation Station, which has the potential to affect student learning outcomes differently. In addition, I^2 statistics are also used to describe the percentage of variation between studies that results from real heterogeneity rather than chance (Higgins & Thompson, 2002). A high I^2 value indicates a significant diversity in the study results. In the context of this study, if the results of the heterogeneity test indicate significant variation between studies regarding the influence of the blended learning type Rotation Station on student learning outcomes, the summary model effect size used is a Random Effect.

On the other hand, if no significant variation is found, then the model is used as a Fixed effect. The analysis of moderator variables was carried out by dividing the study into six groups, namely the Country of origin of the study (Country), learning outcomes (Achievement), total Stations, duration of treatment (treatment duration), sampling techniques (Sampling technique), and the conditions of implementation (Condition). Election Country to see the difference in the influence of the model blended learning type Rotation Station in various regions, considering that each Country has different developments in science, technology, and educational resources that can affect the success of learning (Chiu, 2021). In this study, the publication bias test was carried out using three methods. First Funnel Plot, which is used to visualize the possibility of publication bias in the form of a Funnel. This plot assesses the symmetry of study distributions around the combined effect size, where symmetrical distributions suggest no significant publication bias. Egger's Linear Regression Test statistically evaluates this symmetry, revealing potential publication bias from the effect size and standard error relationship. Additionally, the Fail Safe N method by Rosenthal calculates the number of zero effect size studies needed to invalidate the results, with a higher number indicating stronger evidence that the station rotation model's impact on student learning outcomes is not attributable to publication bias.

RESULT AND DISCUSSION

RESULTS

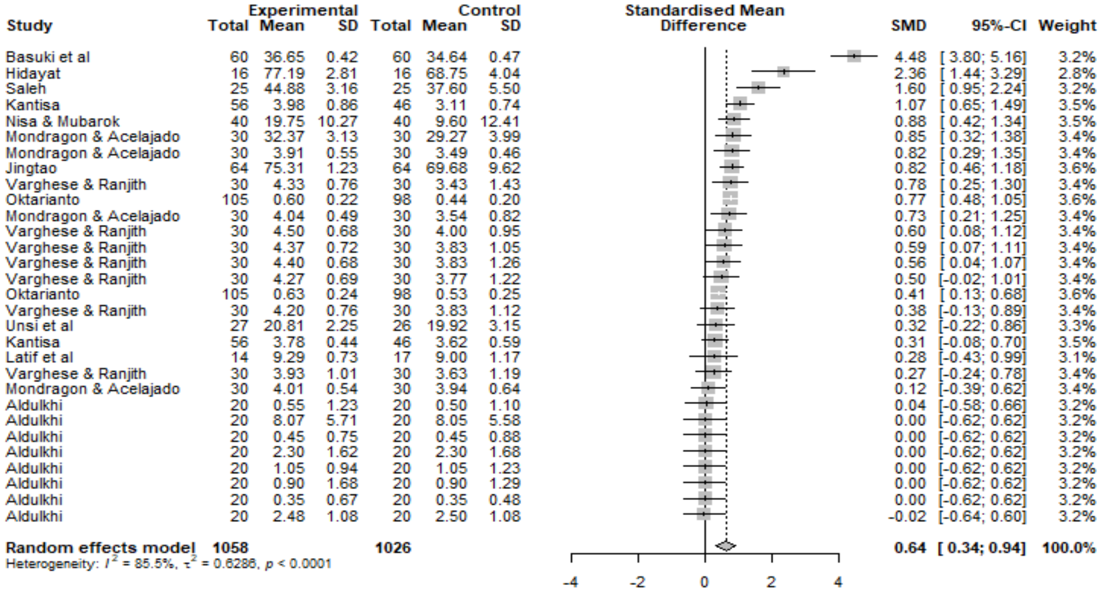
Calculation of effect size and aggregate effect size

This meta-analysis was conducted to determine the magnitude of the effect of applying the blended learning model station rotation on student learning outcomes, based on a synthesis of 30 relevant studies involving a total of 2,084 participants (1,058 in the experimental group and 1,026 in the control group). Most studies showed positive effect size values, indicating that learning with the station rotation model tended to yield better learning outcomes than conventional learning. However, a small number of studies produced negative effect sizes, indicating that in specific contexts, the learning outcomes of the control group were higher than those of the experimental group.

The results of the calculation with the random effects model showed an effect size value of gRE = 0.6379 with a 95% confidence interval [0.3368; 0.9391] and a p< value of 0.0001. Based on the criteria of (Cohen, 1992), this value belongs to the category of "moderate" effects. These findings indicate that overall, the implementation of Rotation Station has a significant contribution to improving student learning outcomes, although the magnitude of the impact varies between studies.

Overall, most of the studies analyzed were concentrated around an aggregate effect size value of 0.64 (95% CI [0.34; 0.94]). Some studies show considerable deviations to the left, which reflects a negative effect size and indicates a lower effect than the mean value. Instead, more studies are shifting toward the right with positive effect sizes, suggesting an impact that is above average. This pattern illustrates the application of the blended learning model, specifically rotation, generally showing a consistent and significant positive impact on improving student learning outcomes. However, there are variations in the success rate between studies, which may be influenced by differences in context, student characteristics, learning materials, and model implementation strategies.

Figure 2. Forest Plot



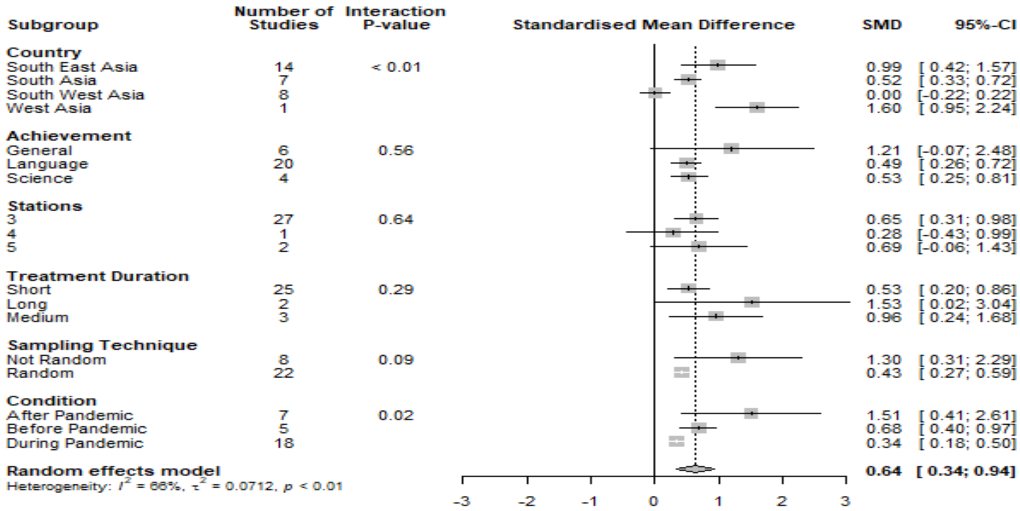
Heterogeneity test

Based on the results of the analysis shown in Figure 1, a Cochran's Q value of 200.45 (df = 29, $p < 0.0001$) was obtained, indicating significant heterogeneity among the studies. An I^2 value of 85.5% (95% CI: 80.4% – 89.3%) indicates a very high level of heterogeneity, while an H^2 value of 2.63 (95% CI: 2.26 – 3.06) indicates that the total variation between studies is more than double the expected variation if the data are homogeneous. Based on the calculation results Figure 3, the value of Q = 4076.65 with a p-value < 0.0001 was obtained. Since the p-value is smaller than $\alpha = 0.05$, the null (H_0) hypothesis that there is no heterogeneity between studies is rejected. This shows significant heterogeneity in the analyzed data. In other words, the effect size obtained from studies on the influence of blended learning type Rotation Station Student learning outcomes show considerable variation, so it is relevant to conduct further analysis using moderator variables. The I^2 value was 85.5% with a 95% confidence interval ranging from 80.4% to 89.3%. If referring to the criteria of (Higgins & Thompson, 2002), this value falls under the category of substantial heterogeneity.

Moderator variable analysis

All moderator variables were analyzed using the ANOVA-like models' approach. In this approach, the within-group effect means (g), 95% confidence interval (CI), and between-group heterogeneity (Qb) were reported. A significant Qb value indicates a significant difference in effect size between the groups in the moderator variable. The moderator analysis procedure is carried out using RStudio version 2023.06.1-524 by utilizing the Meta Package (Balduzzi et al., 2019). The moderator analysis syntax contains analysis based on study characteristics, learning outcome characteristics, and learning design characteristics, according to the moderator variables that have been identified in the previous stage.

Figure 3. Forest Plot Variable Moderator



Moderator country

A moderated analysis by Country showed a statistically significant difference ($p < 0.01$) between study groups from different regions. These findings demonstrate that geographical factors play a crucial role in shaping learning effectiveness, where socio-cultural conditions, educational policies, technological infrastructure, and the readiness of teachers and students can be decisive factors. Studies conducted in Southeast Asia showed the highest effect size (SMD = 0.99; 95% CI [0.42; 1.57]), indicating that the station rotation model has a substantial impact in this region. In South Asia, the effect size produced was in the medium category (SMD = 0.52; 95% CI [0.33; 0.72]). Although not as large as Southeast Asia, these results still show significant effectiveness. A factor that may affect is infrastructure disparities between regions, where some schools already have adequate internet access and devices, while others still face limitations. The difference in the quality of these facilities has the potential to impact the consistency of the station rotation model's application and the results obtained. In contrast, studies in West Asia yielded very high effect sizes (SMD = 1.60; 95% CI [0.95, 2.24]), indicating a substantial impact on improved learning outcomes. This is likely influenced by the high level of financial support for educational innovation in several countries in the region, primarily through digital transformation in education programs. However, studies in Southwest Asia did not show a significant influence (SMD = 0.00; 95% CI [-0.22; 0.22]), which may be due to the lack of integration of learning technologies, differences in curriculum policies, or limitations in teacher training for implementing this model effectively. This contrast reinforces the finding that country background is a crucial factor that must be considered when implementing technology-based learning strategies, such as station rotation-type blended learning.

Moderator achievement

Moderator analysis, based on the type of learning outcomes, was conducted to determine whether the station rotation type blended learning model exhibits different effectiveness when applied to the realms of general achievement, language, and science. The results of the analysis showed that the differences between groups were not statistically significant ($p = 0.56$); therefore, this model can be generally applied across fields. However, the patterns that emerged from the effect size of each category indicated a difference in the tendency of benefits in certain types of achievements.

General outcomes, which included cross-subject skills such as critical thinking, collaboration, and problem-solving, showed the largest effect size (SMD = 1.21; 95% CI [-0.07; 2.48]). Although the confidence interval is quite broad and contains negative values, these results still indicate that the station rotation model has the potential to have a major influence on holistic learning.

Moderator stations

Moderator analysis, based on the number of stations, was conducted to determine whether the variation in the number of rotation points in the station rotation model affected the level of learning effectiveness. In this study, the number of stations is grouped into three categories, namely three stations, four stations, and five stations. The results of the analysis showed that the difference in effect size between groups was not statistically significant ($p = 0.64$). Thus, in general, variations in the number of stations do not have a consistently different impact on student learning outcomes.

However, from the perspective of effect size, an interesting trend emerges. Learning with three stations showed the highest effect size (SMD = 0.65; 95% CI [0.31; 0.98]), which was in the medium category.

Moderator treatment duration

The moderator analysis of the treatment duration aimed to identify the extent to which the duration of the intervention affected the effectiveness of the station rotation model on learning outcomes. In this study, the duration of treatment was grouped into short, medium, and long. The results of the statistical test showed that the difference between the duration groups was not statistically significant ($p = 0.29$). This means that, from the point of view of formal significance, the duration of the intervention does not absolutely determine the magnitude of the effect size. Nonetheless, the effect size pattern that emerges provides important insights. Long-duration interventions yielded the highest effect size (SMD = 1.53; 95% CI [0.22, 3.04]) in the large category. This aligns with the theory of long-term learning, which posits that a longer timeframe enables learners to adapt to learning strategies, internalize concepts, and gradually develop higher-level thinking skills. Over a long duration, students can repeat, practice, and deepen their understanding, making knowledge transfer stronger and more sustainable. The medium duration resulted in an effect size of SMD = 0.96 (95% CI [0.24; 1.68]), which fell within the medium to high category. This suggests that interventions that take place over a moderate time span can yield substantial results, especially if learning planning is mature. Each station cycle is designed to build concept interconnectedness. At this duration, students still have enough time to explore the material without it being too long, thereby avoiding the risk of learning saturation. Meanwhile, short duration had the lowest effect size (SMD = 0.53; 95% CI [0.20; 0.86]), although it was still in the medium category. The low achievement in this duration may be due to time constraints that make students not fully adapt to the station rotation pattern, have not had time to master the necessary technical skills, or have not received optimal reinforcement of the material.

Sampling moderator

The moderator of the sampling technique was used to analyze whether the way participants were selected in the study affected the effectiveness of the station rotation model on learning outcomes. The analyzed studies were grouped into two main categories, namely random sampling and non-random sampling. Statistical analysis showed that the difference in effectiveness between groups was not statistically significant ($p = 0.09$). However, the effect size distribution reveals a distinct pattern that warrants attention. Results showed that studies with non-randomized samples recorded higher effect sizes (SMD = 1.30; 95% CI [0.31, 2.29]) compared to studies with randomized samples (SMD = 0.43; 95% CI [0.27, 0.59]). This difference may be related to the existence of selection bias in non-randomized studies, where selected participants often have certain characteristics that are more prepared or more appropriate for the intervention. For example, teachers or researchers may choose classes that already have better initial ability or higher learning motivation, so that the results of the intervention look more positive than the general population.

Moderator condition

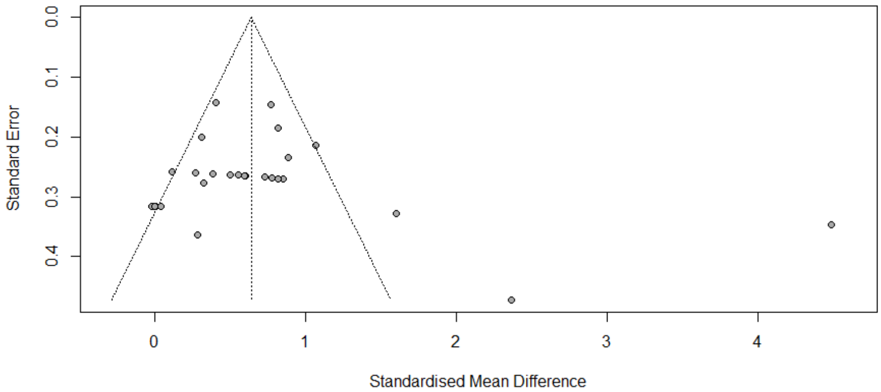
The moderator of the implementation conditions grouped the study based on the implementation time, before the pandemic, during the pandemic, and after the pandemic. The analysis showed a significant difference ($p = 0.02$) in the effectiveness of the station rotation model between the three periods. This indicates that temporal contexts, including the global educational situation and technological readiness at any given time, have a significant contribution to the variation in learning outcomes. The results showed that studies conducted after the pandemic recorded the highest effect size (SMD = 1.51; 95% CI [0.41; 2.61]). These findings can be attributed to the increased adaptation of technology and online learning experiences during the pandemic, which are then optimized in post-pandemic face-to-face learning. Teachers and students in this period have better digital skills, as well as better supporting infrastructure, such as learning devices, internet networks, and LMS platforms, so that the implementation of station rotation becomes more effective. Meanwhile, studies prior to the pandemic showed a moderate effect size (SMD = 0.68; 95% CI [0.40, 0.97]). During this period, the application of the station rotation model tends to face technological limitations and access to digital devices, so the station rotation strategy is more often carried out manually or with minimal technological support. However, this approach still provides benefits in terms of learning differentiation and increased student interaction, although the impact is not as large as in the post-pandemic period. In contrast, studies conducted during the pandemic produced the lowest effect size (SMD = 0.34; 95% CI [0.18; 0.50]). This condition can be explained by the major challenges faced by the world of education at that time, such as the sudden transition to full online learning, limited access to technology for some students, and the lack of experience of teachers in managing virtual station rotation-based learning. With limited face-to-face interaction and reduced teacher control over classroom dynamics, the effectiveness of the station rotation model in this period is less than optimal.

Bias evaluation

Funnel plots were used to identify potential publication bias in this meta-analysis study. This plot maps the Standardized Mean Difference (SMD) on the horizontal axis and the Standard Error (SE) on the vertical axis. The vertical line in the middle shows the combined effect of the meta-analysis results, while the diagonal line forms the confidence interval boundary at various SE levels.

The results of the funnel plot visualization in Figure 3 show that most of the research points are around the central vertical line, with a relatively balanced distribution on both sides. Although there is a slight tendency to skew the distribution to the right, the distribution of the data still shows a point on both sides of the center line. This suggests that the visual indication of publication bias is not very strong.

Figure 3. Funnel Plot



Some of the dots are located far on the bottom right side of the plot, which likely represents a study with a large effect size but a small sample size. The slight asymmetry seen in this graph cannot be definitively concluded as publication bias, because the pattern can also be caused by heterogeneity between studies, differences in research contexts, and variations in methods used. Egger's regression linear test (Egger et al., 1997) is one of the commonly used quantitative methods to test asymmetry in the plot funnel to detect potential publication bias in meta-analysis. In principle, this test performs a linear regression between the normalized effect estimates (the estimated value divided by the Standard Error) as the dependent variable and the precision variable (the reciprocal of the Standard Error) as the independent variable. The interception of this regression is then compared to zero to determine whether there is an asymmetry. In this study, the Egger test was performed using the meta bias function in the RStudio application to detect potential asymmetry in the funnel plot, which can indicate publication bias. The results of the analysis showed that the value of $t = 0.46$, $df = 28$, and the p-value = 0.6475. The p-value obtained is greater than the significance level of $\alpha = 0.05$, so it can be concluded that there is no significant asymmetry in the funnel plot. Analysis Safe N Files is used to detect potential publication bias by assuming the existence of several other unpublished studies. These unpublished studies are assumed to have insignificant results or effect sizes that are close to zero. In this study, Rosenthal's method (Rosnow & Rosenthal, 1996) was used to estimate the number of additional studies required to render the effect size of the combination insignificant or to achieve a p-value greater than 0.05. The calculation was performed using the fsn () function in the RStudio application, with the following results: Observed Significance Level: < 0.0001, Target Significance Level: 0.05, Fail-Safe N: 1834. According to (Rothstein, 2008), when the value of Safe N Files is greater than 5K + 10 (with K being the number of studies), it can be concluded that there is no publication bias. In this study, the number of studies analyzed was 30, so the minimum limit was 5(30) + 10 = 160. Value Safe N Files obtained (1834) far exceeds the minimum limit, so it can be concluded that there is no indication of publication bias in the analyzed study data related to the effect of the use of technology in learning on critical thinking skills.

DISCUSSION

This meta-analysis was conducted to identify the effect of using a blended learning model with station rotation on student learning outcomes, based on a synthesis of 30 relevant studies involving a total of 2,084 participants (1,058 in the experimental group and 1,026 in the control group). The random effects model approach was used to calculate the summary effect size, considering the significant variation between the studies analyzed. The results of the analysis showed a random effect size value of 0.6379 with a 95% confidence interval between 0.3368 and 0.9391, and a p-value of < 0.0001. These findings indicate a positive and statistically significant effect of applying the Station Rotation model on improving student learning outcomes. Interpretation of category effect size according to (Cohen, 1992), value 0.6379 is in the medium to large effects category, which means that the implementation of Rotation Station provide a meaningful substantive impact on learning outcomes. This demonstrates that integrating face-to-face and online learning strategies on a rotating basis can increase engagement, personalize learning, and enhance student understanding. In other words, the application of this model not only provides a variety of learning methods but also facilitates learning differentiation that can adjust to the speed and learning needs of students, thus having a positive impact on their academic achievement. These findings indicate that the Rotation Station, which combines face-to-face learning with the use of digital technology through the rotation of learning stations, makes a positive contribution to improving student learning outcomes. Moderate effects were found, in line with research by (Pattanapichet & Wichadee, 2015) which shows that integrating social media into learning can significantly improve students' academic achievement and critical thinking skills. In the context of the Rotation Station model, hands-on classroom interaction combined with technology-based activities can strengthen concept understanding through both collaborative and independent learning.

These results are also in line with the study (Abdusselam & Karal, 2020) and (M. Akçayır et al., 2016) who found that the use of technology-based augmented reality provide a positive and moderate effect on the achievement of learning outcomes. One reason the effect is moderate is that, while technology helps facilitate high-level learning, there are technical constraints, such as device quality and system stability, that can affect students' learning experience. Obstacles such as limited infrastructure, low student skills in using digital devices, and a lack of training and support for teachers in integrating technology are crucial factors that can reduce the effectiveness of technology-based learning (Akram et al., 2022; Bingimlas, 2009; Costan et al., 2021). Effect size from the application blended learning type Rotation Station Student learning outcomes are heterogeneous, which may be influenced by variations in the research context such as differences in education levels, subjects, duration of treatment, sampling techniques, and implementation conditions. These results are in line with the findings (B.-Z. Li et al., 2020) conducted a meta-analysis study on the flipped classroom, which also found significant heterogeneity between studies. The results of the variable moderator analysis showed that of the six moderators tested, two provided statistically significant effect differences: country and condition. Other moderators, such as the type of learning outcomes, the number of stations, the duration of treatment, and the sampling technique, showed no significant differences; however, the pattern of effect size variation still provided important information in practical terms. In line with research conducted by (Oktarianto et al., 2024) and (Yılmaz & Fırat, 2024) which states that geographical factors can affect learning outcomes and the effectiveness of applying this model. The results of Egger's Linear Regression Test corroborate this finding, with a value of t = 0.46, df = 28, and a p-value of 0.6475, indicating that there is no statistical evidence of asymmetry in the Funnel Plot. The estimated bias value of 0.8418 (SE = 1.8213) also strengthens the conclusion that publication bias is not significant. This condition aligns with the findings of (Anggoro et al., 2025) in a study on the effects of Game-based learning on critical thinking ability, where the form of a Funnel Plot, which is slightly asymmetrical, is not considered substantial.

CONCLUSION

The meta-analysis on the station rotation type blended learning model indicates that its application positively impacts student learning outcomes significantly. This model, which merges face-to-face instruction with technology-based learning, enhances academic achievement compared to traditional methods. The heterogeneity analysis reveals significant variability across studies, suggesting that the effectiveness of the model is context-dependent. Moderator variables, including Country, type of achievement, number of stations, treatment duration, sampling technique, and research conditions, significantly influence effect size. Importantly, no significant publication bias was detected, as demonstrated by the balanced funnel plot and Egger's Linear Regression Test, affirming the credibility of the findings. The results endorse the application of the station rotation model as effective and consistent in improving learning outcomes across diverse educational settings. Moreover, the study highlights practical implications for technology-based learning development, directing educators and policymakers towards adapting the model to specific learner characteristics and school contexts. It emphasizes the need for teacher training and infrastructure support, positing that enhancing teachers' competencies in this model's management is crucial for its success. Furthermore, it calls for future research on additional moderator variables and the model's influence on various 21st-century skills, including critical thinking and student motivation.

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