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Effectiveness of Think-Pair-Share and STEM Models on Critical Thinking in Early Childhood Education

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Abstract

This study aims to determine the effectiveness of the STEM-based Think Pair Share model on the thinking ability of early childhood education students. The research is a meta-analysis research. This study analyzed 17 primary studies that had met the established inclusion criteria. The data analysis in this study is statistical analysis. This study concluded that the analysis using the random effect model obtained the average effect size value (d= 0.972; p <0.001). This effect size is very high. These results show that the STEM-based Think Pair Share model strongly influences the critical thinking ability of prospective Early Childhood Education (PAUD) teachers compared to the traditional learning model.

Keywords: *Think Pair Share Model; STEM; Meta-analysis; Critical Thinking*

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Introduction

Critical thinking skills are one of the main competencies that must be possessed in the 21st century era, especially for prospective early childhood education teachers (Dahlberg et al., 2013). As educators who play a role in shaping the early foundations of child development, prospective PAUD teachers are required not only to master teaching materials, but also to be able to think analytically, logically, and reflectively in dealing with various situations in the classroom (Ültay, 2022; Özkan, 2024). These skills enable prospective teachers to design appropriate learning strategies, assess learners' learning needs in depth, and provide solutions to problems that arise during the learning process. In the context of early childhood education, critical thinking is important because children need guidance that is not only knowledge-based, but also

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developmentally appropriate thinking stimulation (Günşen et al., 2024; Nurtamam et al., 2023).

In addition, critical thinking skills also support PAUD teacher candidates in developing more adaptive and flexible teaching abilities (Hägglund et al., 2007). With this ability, they can evaluate the learning approach applied, modify it according to student needs, and respond better to changes in the dynamics of education (Tobin, 2010; Haslip & Gullo, 2018). In an educational process that is increasingly complex and influenced by various factors, prospective teachers with critical thinking skills will be better able to integrate technology, pedagogical innovations and relevant learning approaches to help children reach their full potential. This makes critical thinking an important cornerstone in improving teaching effectiveness at the basic education level such as PAUD (Kaga, 2008).

Early childhood education is a crucial phase in a child's development, where the early foundations of knowledge, character and social skills are formed. Educators at the Early Childhood Education level play an important role in creating a learning environment that supports children's holistic development. To achieve this, educators need to be able to think critically (Peters, 2012), as they must be able to identify the unique needs of each child and design learning that is not only informative but also creative and innovative. Teachers who think critically can explore different teaching methods, such as using educational games or project-based activities, to stimulate children's cognitive, social and emotional skills (Bakken et al., 2017).

In addition, critical thinking enables early childhood educators to bring innovative learning approaches, integrating technology and developmentally appropriate learning methodologies(Kiviranta et al., 2024). They are able to evaluate the effectiveness of traditional learning methods and look for better alternatives, such as utilising digital media or STEM (Science, Technology, Engineering, and Mathematics) in the teaching and learning process. With these skills, Early Childhood Education teachers can create an engaging and dynamic learning environment that encourages children's creativity and imagination, while preparing them for future challenges. Innovation in early childhood education learning not only increases children's interest in learning, but also helps them develop critical thinking skills early on.

Many prospective Early Childhood Education teachers still face major challenges in developing adequate critical thinking skills (Bakken et al., 2017). This has an impact on their limitations in designing learning that is innovative and responsive to children's needs. Their lack of critical thinking skills means they tend to rely on conventional teaching methods that lack cognitive stimulation and creativity (Ültay, 2022). In fact, ECD education requires a dynamic approach, where children can be actively involved in learning that is appropriate to their stage of development. Prospective teachers who lack critical thinking skills often have difficulty in assessing learning situations holistically, and are therefore unable to design effective strategies to increase children's engagement and understanding.

There is also a lack of self-development and training opportunities that emphasise strengthening critical thinking skills in early childhood education teachers. In many cases, ECE teacher education programmes have not optimally provided learning that facilitates the enhancement of these skills (Hägglund et al., 2007; Moss, 2007). As a result, prospective teachers find it difficult to adjust to the demands of the 21st century that require them to master creative, innovative and problem-solving-based learning methods. Without good critical thinking skills, prospective ECE teachers will find it more difficult to solve problems that arise in the classroom, reflect on learning practices, and innovate in presenting methods that suit

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the needs of children(Damayanti et al., 2024). Therefore, it is necessary to have a model that is able to encourage the critical thinking skills of prospective early childhood education teachers, namely the Think Pair Share and STEM (TPS-STEM) model.

The Think Pair Share model is a cooperative learning model designed to encourage active participation and deep understanding through interaction between students (Tanujaya & Mumu, 2019; Persaud & Persaud, 2019). In this model, students are given time to think individually about a question or topic, then pair up with a friend to discuss their ideas before sharing their findings or thoughts with the whole class (Boleng et al., 2021). This approach not only helps students develop critical and analytical thinking skills, but also strengthens communication and collaboration skills. TPS allows students to reflect and expand their knowledge by listening to different perspectives, thus creating a more inclusive and dynamic learning atmosphere (Yotha et al., 2024). In addition, this model is very effective in helping students who may be hesitant to speak in front of a large class, as they have the opportunity to discuss in small groups first.

Furthermore, Science Technology Engineering Mathematics (STEM) is an integrated learning approach that combines the four disciplines to provide students with a holistic and applicative understanding of the concepts studied(Hernández-Matías et al., 2023). The STEM approach not only focuses on theory, but also emphasizes problem-solving, innovation, and critical thinking—competencies that are critical in the ever-evolving age of technology (Csaba & Szabo 2021; Pertiwi et al., 2024; Morales et al., 2022). Through STEM-based learning, students are invited to connect theory with practice through experiments, collaborative projects, and technological exploration, so that they can understand the relevance of science in real life (Zulyusri et al., 2023; Zulkifli et al., 2022). In addition, STEM plays a role in preparing students to participate in future industries that are heavily influenced by science and technology, making them better prepared to face global challenges and take advantage of diverse career opportunities in various sectors (Chaerunisa et al., 2023).

Many studies have identified that the Think Pair Share and STEM models can improve critical thinking skills learning (Sari et al., 2013; Kurjum et al., 2020; (Wuryandani & Herwin, 2021; Li & Tu, 2024; Sattar & Nawaz, 2024; Yaqutunnafis, 2024), keterampilan berpikir kreatif dan Abad-21 (Zainil et al., 2023; Liline et al., 2024). However, the results of the study are inconsistent in the same topic. Meanwhile, Islamic Religious Education learning teachers want to consider the effectiveness of the Think Pair Share model to improve students' critical thinking skills. Based on this, efforts are needed to combine previous findings related to the influence of the Think Pair Share and STEM (TPS-STEM) model on students' critical thinking skills in learning Islamic religious education to be evaluated quantitatively. In this case, a meta-analysis approach is used to evaluate previous research to obtain consistent and accurate conclusions (Badawi et al., 2023; Tamur et al., 2020; Borenstein et al., 2007). The purpose of this study is to find out the magnitude of the influence. The magnitude of influence is the size of the influence, the magnitude of the difference and the relationship between variables (Badawi et al., 2023).

Based on previous research that has been researched, there has been no meta-analysis research related to the influence of the Think Pair Share STEM (TPS-STEM) model on critical thinking skills in Islamic religious education learning. Therefore, this study aims to measure the influence of the Think Pair Share STEM (TPS-STEM) model on critical thinking Prospective Early Childhood Education Teacher Students.

Methodology

This research is a type of meta-analysis research. Meta-analysis research is a type of research that searches and analyzes primary research statistically to reach a conclusion (Öztop, 2023; Hidayah et al., 2023; Taşdemir, 2022). Furthermore, this meta-analysis research was used to find out the shortcomings of previous research (Hidayah et al., 2023). This meta-analysis

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aims to determine the influence of the Think Pair Share and STEM Learning models on students' critical thinking skills of Prospective Early Childhood Education Teacher Students.

To obtain data that has good validity and reliability, it is necessary to pay attention to the eligibility criteria, namely 1) the research must come from the Google Scholar, DOAJ, ERIC, Wiley and Scopus databases, 2) The research journal must be indexed by SINTA, Web of Science and Scopus, 3) The research topic must be relevant, 4) The research was published in the 2021-2024 time frame, 5) The research has > 25 students and has complete data to calculate the effect size value.

Table 1. Category Effect Size Value

Effect Size	Category
Between -0.15 and 0.15	No effect
Between 0.15 and 0.40	Small Effect
Between 0.40 and 0.75	Moderate Effect
Between 0.75 and 1.10	High effect
Between 1.10 and 1.45	Very High Effect
1.45 or higher	Amazing Effect

Source:(Setiawan et al., 2022; Bachtiar et al., 2023; Borenstein et al., 2007; Asnur et al., 2024)

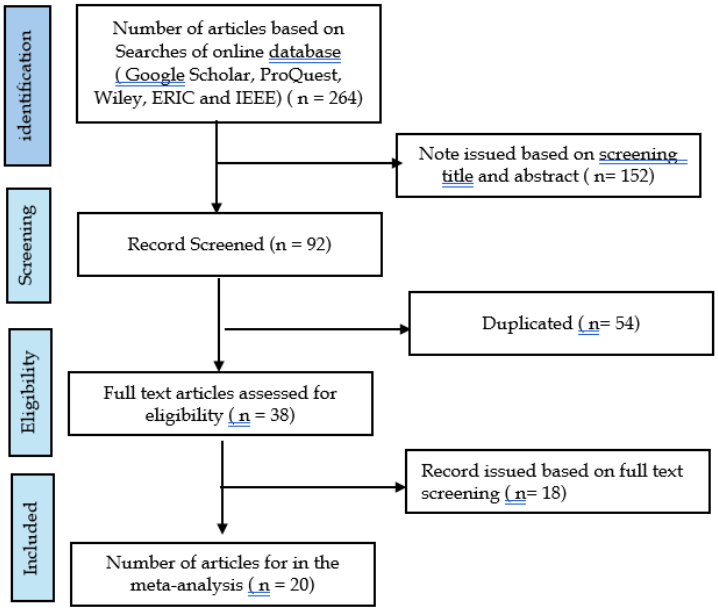

Figure 1. Data Selection Process Through PRISMA

The research data collection process is related to the influence of the Think Pair Share and STEM (TPS-STEM) model on thinking skills in learning Islamic religious education. Data was obtained through the Google Scholar journal database, ScienceDirect, IEEE, ERIC and Mendeley. The data search keyword is "Think Pair Share mode"; "STEM Learning"; "The Influence of the Think Pair Share Model"; The Influence of STEM Learning on Critical Thinking Skills"; The Effect of the Think Pair Share and STEM Model (TPS-STEM) on Critical Thinking ;The Influence of TPS-STEM on the Critical Thinking Skills of Prospective Early Childhood Education Teachers.The data selection process through the PRISMA 2020 method consists of identification, Screening, Eligibility, and Included (Figure 1.). From the results of data selection, 20 studies that met the inclusion criteria can be seen in Table 2.

Data analysis in this study calculates the effect size value of each study analyzed. The effect size value in this study is to calculate the effectiveness of think pair share and stem models on critical thinking skills of prospective early childhood education teacher students.

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According to (Borenstein et al., 2007) The stages of data analysis in the meta-analysis can be seen in (Figure 1.). Furthermore, the criteria for the effect size value in the study can be seen in Table 1.

Result and Discussion

Based on the results of the data search through the database, 20 studies/articles met the inclusion criteria. The effect size and standard error can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Jurnal	Years	Effect Size	Standard Error
KP 1	2022	2.10	0.34
KP 2	2023	1.19	0.37
KP 3	2023	0.66	0.47
KP 4	2024	2.45	0.39
KP 5	2024	0.92	0.28
KP 6	2024	1.19	0.47
KP 7	2024	0.45	0.12
KP 8	2024	0.38	0.40
KP 9	2022	1.13	0.35
KP 10	2024	1.02	0.33
KP 11	2022	0.72	0.35
KP 12	2024	1.18	0.40
KP 13	2022	0.91	0.43
KP 14	2022	0.77	0.32
KP 15	2024	0.69	0.34
KP 16	2023	0.71	0.23
KP 17	2024	0.94	0.35

Based on Table 2, the effect size value of the 24 studies ranged from 0.38 to 2.45. According to Borenstein et al., (2007) Of the 20 effect sizes, 6 studies (35.29%) had medium criteria effect sizes, and 11 studies (64.70%) had high criteria effect size values. Furthermore, 17 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Fixed and Random effect

	Q	df	p
Omnibus test of Coefficients Model	46.119	1	< 0.001
Test of Residual Heterogeneity	96.921	16	< 0.001

Based on Table 3, a Q value of 96.921 was obtained, higher than the value of 46.119 with a coefficient interval of 95% and a p-value of 0.001 <. The findings show that the value of 20 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail-safe N (FSN) test (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007; Badawi et al., 2023). The results of checking publication bias with a funnel plot can be seen in Figure 2.

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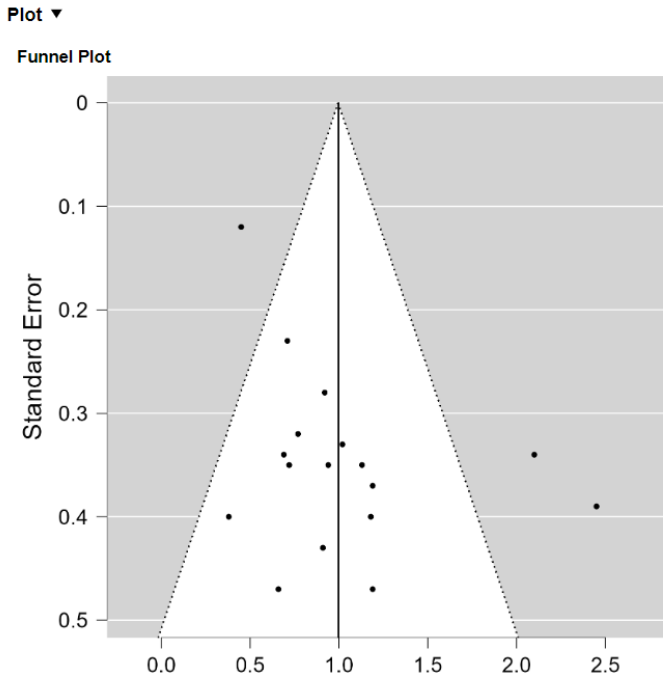

Figure 2. Funnel Plot Effect Size

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail-Safe N (FSN) test. The results of the Rosenthal Fail-Safe N calculation can be seen in Table 4.

Tabel 4. Fail-Safe N

File Drawer Analysis			
	Fail Safe N	**Target Significance**	**Observed Significance**
Rosenthal	1052	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 1636 is greater than the value of 5k + 10 = 5(17) + 10 = 95, so it can be concluded that the analysis of 17 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, the p-value is calculated to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Tabel 5. Summary/ Mean Effect Size

Coefficient						
	Effect Size	**Standard Error**	**z**	**p**	**Coefficient Interval**	
					Lower	Upper
Intercept	0.972	0.278	9.107	< 0.01	0.821	1.019

Based on Table 5. The summary effect size value is 0.972 and the standard error is 0.278. This finding shows the effect of the Think Pair Share and STEM (STEM) model on students' critical thinking skills **of** Prospective Early Childhood Education Teacher Students.The effect size category is very high with a value of Z = 9.107 and p < 0.001, so this model has a positive effect in encouraging students' critical thinking skills in learning Islamic religious education at school. This research is in line with Ugwu, (2019) Think Pair Share model can improve students' reading and critical thinking skills in learning Islamic religious education. The results

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are in accordance with the (2015) Think Pair share model that positively influences students' critical thinking skills in the learning process.

Think Pair Share (TPS) can encourage students in individual thinking, pair discussion, and sharing results with the group. In the context of PAI, the Think Pair Share model encourages students to identify problems, think independently (Samsudin et al., 2021), then share and discuss ideas with a partner, thus training students to think critically (Usman et al., 2015; Tanujaya & Mumu, 2019). When students are challenged to discuss religious or moral issues in PAI, their critical thinking skills are enhanced through open dialogue involving analysis, evaluation, and justification of arguments based on valid of prospective early childhood education teacher students. Research by (Ashidiq et al., 2024) STEM model is effective to improve students' thinking skills of Prospective Early Childhood Education Teacher Students (Eadie et al., 2024).

Furthermore, the Think Pair Share and STEM (TPS-STEM) learning model provides better in improving critical thinking skills is expected to be achieved. In the Think Pair Share and STEM (TPS-STEM) model, students engage in discussions that strengthen their critical thinking skills (Zainil et al., 2023), while STEM provides intellectual challenges that require problem solving and data-based analysis. Students are encouraged to think logically, analyze data, and seek solutions that are not only in accordance with the principles of science, but also in line with religious teachings (Samsudin et al., 2021; Nuraini et al., 2019; Hacioğlu & Gülhan, 2021). Thus, TPS-STEM creates a holistic learning environment that strengthens students' cognitive and spiritual aspects. PAUD learning using the TPS-STEM model becomes more contextualized because students are exposed to real situations that require the application of Islamic values and STEM principles(Topano et al., 2023). For example, in a discussion on environmental ethics or technology in PAUD, students are not only required to understand Islamic teachings related to the topic, but also to analyze and solve problems based on scientific facts (Bakken et al., 2017). Through this approach, students not only gain cognitive knowledge but also the ability to apply it in relevant real-life situations, which in turn improves critical thinking skills (Ashidiq et al., 2024).

The application of TPS-STEM in PAUD has far-reaching implications for 21st-century education, where critical thinking, collaboration, and problem-solving skills are becoming increasingly important(Pahrudin et al., 2021). By combining these two approaches, students are equipped with strong academic abilities and moral and ethical values relevant to the challenges of the modern world. The implementation of TPS-STEM is expected to produce students who are not only able to think critically but also can adapt to rapid technological and social changes, while still upholding religious principles(Yefang et al., 2024; Adhelacahya et al., 2023;Tanujaya & Mumu, 2019).

Conclusion

From the results of this meta-analysis research, it can be concluded that the application of the Think Pair Sahre and STEM (TPS-STEM) model has a higher effect on students' critical thinking skills in PAI learning than traditional learning models. The results of the analysis using the random effect model obtained an average effect size value ($d = 1.13$; $p < 0.001$). This effect size is classified as very high. Through the TPS model, students are encouraged to think independently, discuss with friends, and share ideas in groups, which enriches their understanding and strengthens their analysis and evaluation skills. The problem-solving-based STEM approach also provides intellectual challenges relevant to daily life, motivating students to think logically and systematically in dealing with Islamic values and science issues.

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