The Effect Project Based Learning Model Based E-Learning on Students' Critical Thinking Skills: A – Meta-analysis

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Abstract
This study aims to determine the effect of project-based learning model based on e-learning on students’ critical thinking skills. This research is a type of meta-analysis research. The data sources in this study came from 12 articles obtained from the journal database published from 2016-2023. Of these, the process of searching data through Google Scholar, Wiley, ScienceDirect and ERIC. The data filtering process was carried out using the PRISMA method. Data analysis is quantitative analysis by calculating the effect size value of the article with the help of the Comprehensive Meta-analysis (CMA) version 3.0 application. The results of the analysis of 12 articles showed that the overall effect size of the e-learning based project-based learning model was statistically significant (rRE = 1.45; P < 0.001; 95 % CI (0.427; 1.19). This finding shows that the implementation of project-based learning model based on E-Learning provides a high influence on students' critical thinking skills. The findings of this meta-analysis provide a great contribution in developing learning models to encourage students' critical thinking skills in schools.

Keywords: Education, Project Based Learning, Meta-analysis, Critical Thinking

Abstrak
Penelitian ini bertujuan untuk mengetahui pengaruh model project based learning berbasis e-learning terhadap keterampilan berpikir kritis siswa. Penelitian ini adalah jenis penelitian meta-analisis. Sumber data dalam penelitian ini berasal dari 12 artikel yang diperoleh dari database jurnal yang terbit dari tahun 2016-2023. Dari jumlah tersebut, proses pencarian data melalui google Scholar, Wiley, ScienceDirect dan ERIC. Proses penyaringan data dilakukan dengan metode PRISMA. Analisis data adalah analisis kuantitatif dengan menghitung nilai effect size artikel dengan bantuan aplikasi Comprehensive Meta-analysis (CMA) versi 3.0. Hasil analisis 12 artikel menunjukkan efek size keseluruhan model project based learning berbasis e-learning berpengaruh signifikan secara statistik (rRE = 1.45; P < 0.001; 95 % CI (0.427; 1.19). Temuan ini menunjukkan bahwa penerapan model project based learning berbasis E-Learning memberikan pengaruh yang tinggi terhadap kemampuan berpikir kritis siswa. Temuan meta-analisis ini memberikan kontribusi besar dalam mengembangkan model pembelajaran untuk mendorong keterampilan berpikir kritis siswa di sekolah.

Kata Kunci: Pendidikan, Project Based Learning, Meta-analysis, Berpikir Kritis
Introduction

Critical thinking is an ability that students must have to solve problems in everyday life (Elfira et al., 2023; Rahman et al., 2023; Suharyat et al., 2022). According to Berry & Kowal (2022), critical thinking is an ability that helps students to provide solutions in problem solving. Students who have critical thinking skills are more active and creative in learning (Hariyanto et al., 2022; Suharyat et al., 2022; Farizi et al., 2019; Zulkifli et al., 2022). In addition, critical thinking skills are essential for students in understanding and analysing learning materials (Dahliana & Khaldun, 2018; Ristanto et al., 2022; Chusni et al., 2022). Critical thinking skills help students in drawing a conclusion so that students can solve a problem in learning (Fikriyatii et al., 2022; Gürler et al., 2023).

But in reality, students' critical thinking skills at school are still relatively low (Suryono et al., 2023; Nurtamam et al., 2023; Anjarwati et al., 2022; Fradila et al., 2021). It can be seen that the learning process is still teacher-centred and the learning method is still conventional so that it does not encourage students' critical thinking skills (Hasnan & Fitria, 2020; Suharyat et al., 2023; Ichsan et al., 2022). Learning activities delivered by teachers contain too much material and concepts that do not train students to think critically (Purwanto et al., 2012; Hamengkubuwono et al., 2016; Sofianora et al., 2023). Furthermore, learning does not involve students to be active in solving a problem (Mahfudz et al., 2023; Supratman et al., 2021; Luciana et al., 2023; Ichsan et al., 2022). Therefore, teachers need to improve learning models that can encourage students' critical thinking skills.

The project-based learning model is a learning model that can help (Maret Gulo, Envilwan Berkat Hareva, Arisman Telambauna, Aprianus Telambauna Sudrajat1*, Abdul Rahman2, Muhammad Isa Anshory3, Hardiansyah Ma’sum3, Siti Aisyah4, Tomi Apra Santosa students think critically in learning (Tuaputty et al., 2023). Project-based learning is a learning model that trains students to learn independently to create a project (Niswara et al., 2019; Rahman et al., 2023; Listiqowati, 2022). Project-based learning model helps students to be more creative and improve students' collaborative ability in learning (Issa et al., 2021; Syawaludin et al., 2022). Research results (Jagantara et al., 2014) Project-based learning can improve student learning outcomes. In addition, the project-based learning model helps students learn to think creatively to find solutions in solving a problem (Vidergor, 2022; Aminah, 2022).

Furthermore, the project-based learning model based on e-learning helps students master learning technology. E-learning is learning that is done online through computers, laptops, mobile phones, tablets and others (Santosa et al., 2021; Baji et al., 2022; Bismala et al., 2022; Uyar, 2023). E-learning-based learning can help students' independent learning process and understanding of learning concepts.
Learning through e-leaning is able to help the student learning process more interesting, creative and interactive (Aurora & Effendi, 2019). So, the project-based learning model based on e-learning needs to be applied in the learning process at school.

Research results (Azis, 2017) The implementation of the project-based learning model can develop literacy and creativity as well as student learning outcomes. Research (Niswara et al., 2019) The project-based learning model has a significant effect on students' higher order thinking skills. However, there is no meta-analysis of the effect size of e-learning-based project-based learning model on students' critical thinking skills. Therefore, this study aims to determine the effect of project-based learning model based on e-learning on students' critical thinking skills.

Research Methods

This research is a type of meta-analysis research. Meta-analysis is a type of research that analyses previous research that can be analysed quantitatively (Balem, 2018); (Razak et al., 2021; Supriyadi et al., 2023; Putra et al., 2023; Karim et al., 2023; Suparman et al., 2021). This meta-analysis study aims to determine the effect of project-based learning model based on e-learning on students' critical thinking skills. The data sources in this study came from 12 national and international journals indexed by SINTA and Scopus. The process of searching for data sources through Google Scholar, ERIC, ScienceDirect and Wiley. The process of selecting data sources through the PRISMA method in Figure 1.

The inclusion criteria in this study are 1) research must be published from 2016-2023; 2) The research comes from SINTA and Scopus indexed journals and proceedings; 3) the research has an experimental class and a control class; 4) Research must be in Indonesian and English; 5) Research must have a relationship with the E-learning-based project-based learning model; 6) research must report the value of (t), (r) and (F) and have a sample size (N)> 20 students. Data analysis in the study by calculating the effect size value of each study with the help of Comprehensive meta-analysis (CMA) application. According to (Cohen, 1988) The effect criteria in meta-analysis research are $0 < d < 0.20$ small criteria, $0.20 < d < 0.80$ medium criteria and $d > 0.80$ high criteria.

Result and Discussion

From the analysis of 129 studies on the effect of E-learning-based project-based learning model on students' creative thinking skills, there were only 12 studies that met the inclusion criteria. Furthermore, studies that have met the inclusion criteria are analysed based on research characteristics consisting of the researcher's name, sample size (N), value (t), (r) and (F), and publication type. The results of sample analysis based on research characteristics can be seen in Table 2.
Table 2. Sample analysis based on research characteristics

<table>
<thead>
<tr>
<th>Kode Jurnal</th>
<th>Country</th>
<th>N</th>
<th>r</th>
<th>t</th>
<th>F</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Indonesia</td>
<td>90</td>
<td>0.94</td>
<td></td>
<td></td>
<td>Scopus</td>
</tr>
<tr>
<td>A2</td>
<td>Indonesia</td>
<td>40</td>
<td>0.85</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A3</td>
<td>Turki</td>
<td>32</td>
<td>1.82</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A4</td>
<td>India</td>
<td>75</td>
<td>0.84</td>
<td></td>
<td></td>
<td>Scopus</td>
</tr>
<tr>
<td>A5</td>
<td>Indonesia</td>
<td>20</td>
<td>0.91</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A6</td>
<td>Indonesia</td>
<td>56</td>
<td>1.25</td>
<td>3.54</td>
<td></td>
<td>Scopus</td>
</tr>
<tr>
<td>A7</td>
<td>China</td>
<td>48</td>
<td>1.31</td>
<td></td>
<td></td>
<td>Scopus</td>
</tr>
<tr>
<td>A8</td>
<td>Turki</td>
<td>140</td>
<td>2.10</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A9</td>
<td>Indian</td>
<td>36</td>
<td>1.34</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A10</td>
<td>India</td>
<td>45</td>
<td>2.82</td>
<td></td>
<td></td>
<td>Scopus</td>
</tr>
<tr>
<td>A11</td>
<td>Indonesia</td>
<td>84</td>
<td>0.65</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
<tr>
<td>A12</td>
<td>Indonesia</td>
<td>28</td>
<td>1.30</td>
<td></td>
<td></td>
<td>SINTA</td>
</tr>
</tbody>
</table>

Table 2. explains data analysis based on researcher characteristics where the sample size (N) ranges from 20-140 students and 7 publications from SINTA indexed national journals and 3 publications from Scopus indexed international journals. Furthermore, before conducting hypothesis testing, we must first conduct a heterogeneity test of each research effect size. The results of the heterogeneity test can be seen in Table 3. And Table 4

Table 3. Heterogeneity Test Results

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omnibus test of Model Coefficients</td>
<td>99.114</td>
<td>1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Test of Residual Heterogeneity</td>
<td>572.349</td>
<td>11</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Note. p value are approximate

Table 4. The Residual Heterogeneity Test Result

<table>
<thead>
<tr>
<th>Estimates</th>
<th>Lower bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>τ²</td>
<td>0.7448</td>
<td>0.3651</td>
</tr>
<tr>
<td>τ</td>
<td>0.6170</td>
<td>0.5240</td>
</tr>
<tr>
<td>I²(%)</td>
<td>98.228</td>
<td>95.4782</td>
</tr>
<tr>
<td>H²</td>
<td>47.560</td>
<td>28.2231</td>
</tr>
</tbody>
</table>

Based on tables 3 and 4, it explains that the 8 studies are heterogeneously distributed. This can be seen from the p value <0.001; Q = 99.114; τ² or τ > 0 and I² (%) = 98.228 close to 100%. The next step is to calculate the summary effect value or mean
effect size of the entire research sample. The results of the summary effect size test or mean effect size can be seen in Table 5.

Table 5. Hajj Summary Effect Size or Mean Effect Size test

<table>
<thead>
<tr>
<th>Estimates</th>
<th>Standard Error</th>
<th>z</th>
<th>p</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.857</td>
<td>0.2728</td>
<td>8.449</td>
<td>&lt; 0.001</td>
<td>0.834</td>
</tr>
</tbody>
</table>

Based on Table 5, explains that the value of Z = 8.449; p < 0.001. This result shows that the application of project-based learning model based on e-learning has an effect on students’ critical thinking skills. Furthermore, the results can be categorised as high effect based on the estimated standard error value of 0.857 [0.834; 1.416]. In addition, the summary effect size analysis test can be described by the forest plot in Figure 2.

Based on Figure 2, explains that the overall effect size of the study has a significant effect. Furthermore, knowing the publication bias of each study. In this meta-analysis research, publication bias can be known by using funnel plot. Funnel plot effect size of the entire study can be seen in Figure 3.
Figure 3. Funnel Plot Standard Error

Based on Figure 3, explains that the points of the study that are extended domina are in the middle of the curve. This shows the effect size but it is difficult to determine whether this meta-analysis is symmetrical or asymmetrical so it is necessary to do the Egger test. The results of the Egger test can be seen in Table 6.

<table>
<thead>
<tr>
<th></th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>sei</td>
<td>1.019</td>
<td>1.292</td>
</tr>
</tbody>
</table>

Table 6. Explaining the p-value > 0.05, the funnel plot distribution is symmetrical. The funnel plot shows that there is no publication bias in this study. Furthermore, to increase the validity of publication bias, it is necessary to conduct the Fail Safe N (FSN) test. The results of the fail safe N test can be seen in Table 7.

<table>
<thead>
<tr>
<th></th>
<th>Fail safe N</th>
<th>Target Significance</th>
<th>Observed significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosenthal</td>
<td>589</td>
<td>0.050</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Based on table 7. The fail safe N (FSN) value is 589. Furthermore, the value of fail safe N is compared with the value of \( k = (5.12) + 10 = 70 \). Therefore, the value of fail safe N \( 589 / 70 = 8.414 > 0.05 \) means that in this meta-analysis study there is no publication bias so there is no need to add or eliminate research.
Discussion

From the analysis of 129 studies on the effect of the project-based learning model based on e-learning, only 12 journals were obtained that met the inclusion criteria. From the analysis of research that has met the criteria illustrates a significant influence on students' critical thinking skills. This result can be seen from the summary effect size or mean effect size (ES = 0.57; p < 0.001; CI 95% = [0.834; 1.416]). The e-learning-based project-based learning model helps students to be more active and creative in learning so as to encourage students' critical thinking skills (Balemen, 2018; Merris et al., 2021; Suteja & Setiawan, 2021). Project-based learning helps students learn more independently and collaboratively and think critically (Nawangsari et al., 2022; Issa, 2021; Supriyadi et al., 2023).

Research results Sumarni & Kadarwati (2020) The project-based learning model can train students' problem-solving skills. The project-based learning model based on e-learning encourages students to be more innovative in mastering technology (Saripudin et al., 2015; Mutakinati & Anwari, 2018). Furthermore, project-based learning trains students' creativity, interest and motivation to learn (Biazus & Mahtari, 2022; Mursid et al., 2022); Razak et al., 2021). The project-based learning model based on e-learning aims to make students explain the concepts that have been taught (Trisdiono et al., 2019; Wanglang & Chatwattana, 2023; Rochmawati & Ridlo, 2020).

Furthermore, there is no publication bias in this study. The results can be seen in the funnel plot which depicts the effect size within the vertical line. Furthermore, from the Egger test results in table 6. Explaining the value (z = 1.019; p > 0.05, the publication bias in the meta-analysis is symmetrical. Analysis of publication bias is very important to test the research hypothesis (Diaih et al., 2022; Yildirim, 2022; Yusuf, 2023). In addition, research bias influences whether or not research hypotheses are accepted (Kaçar et al., 2021). Thus, in this meta-analysis study the entire study was resistant to publication bias.

The project-based learning model based on e-learning is very effective in encouraging students' critical thinking skills. E-learning-based learning helps teachers and students to be creative in creating learning materials (Smolinski et al., 2023; Zhenchenko et al., 2022). E-learning trains students to be able to access information more quickly through the internet so that it increases students' knowledge in learning (Bahçekapılı, 2023). Knowledge is all information obtained by students through various sources. (Ferry et al., 2019; Santosa et al., 2021). Therefore, the existence of knowledge helps students have critical thinking skills in learning.

Conclusion

From this meta-analysis research, it can be concluded that the overall effect size of the project-based learning model based on e-learning is statistically significant (rRE = 0.857; P < 0.001; 95% CI (0.834; 1.416). This finding shows that the implementation of project-based learning model based on E-Learning provides a high influence on students' critical thinking skills. The findings of this meta-analysis provide a major contribution in developing learning models to encourage students' critical thinking skills in schools.

Reference


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