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 (r_{RE} = 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. Prsoes penyaringan data dilakukan dengan metode PRISMA. Analisis data adalah analisis kuantitatif dengan menghitung nilai effect size artikel dengan bantuan aplikasi Comprehensive Meta-analisis (CMA) versi 3.0. Hasil analisis 12 artikel menunjukan effek size keseluruhan model project based learning berbasis e-learning berpengaruh signifikan secara statistik (r_{RE} = 1.45; $P < 0.001$; 95 % CI (0.427; 1.19). Temuan ini menunjukan bahwa penerapaan model project based learning berbasis E-Learning memberikan pemgaruh yang tinggi terhadap kemampuan berpikir kritis siswa. Temuan meta-analisis ini memberikan kontribusi besar dalam mengembangkan model pembelajaran untuk mendorong keterampilan berpikis kritis siswa di sekolah.

Kata Kunci: Pendidikan, Project Based Learning, Meta-analysis, Berpkir 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 (**Mareti Gulo, Envilwan Berkat Hareva, Arisman Telaumbauna, Aprianus Telaumbauna Sudrajat[1*], Abdul Rahman[2], Muhammad Isa Anshory[3], Hardiansyah Ma'sum[3], Siti Aisyah[4], 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

(Wayan Santyasa et al., 2021; Ucar & Yilmaz, 2023). 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 (Balemen, 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

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

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

	Q	df	p
Omnibus test of Model Coefficients	99.114	1	< 0.001
Test of Residual Heterogeneity	572.349	11	< 0.001

Note. *p value are approximate*

Table 4. The Residual Heterogeneity Test Result

|	Estimates	Lower bound	Upper Bound
τ^2	0.7448	0.3651	0.9110
τ	0.6170	0.5240	0.9651
I^2 (%)	98.228	95.4782	99. 772
H^2	47.560	28.2231	56.558

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; τ^2 or t> 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

	Estimates	Standard Error	z	p	Lower bound	Upper bound
Intercept	0.857	0.2728	8.449	< 0.001	0.834	1.416

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.
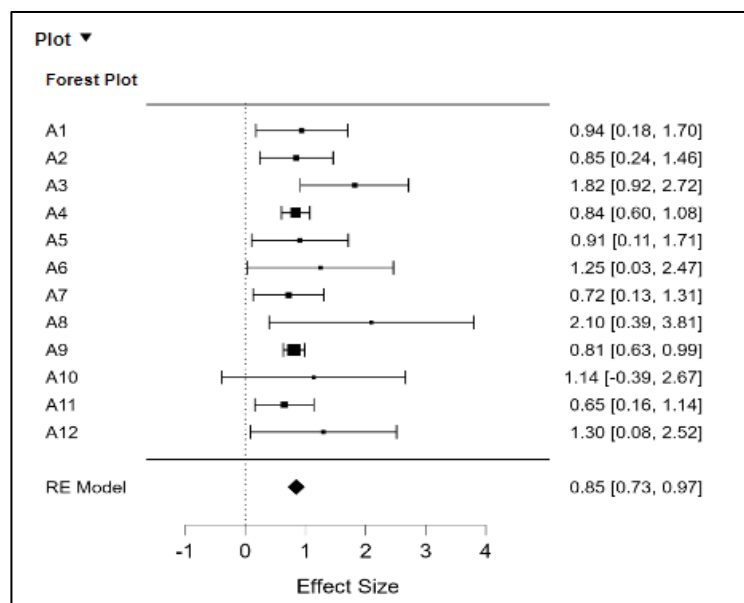
Figure 2. Forest Plot

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 flot effect size of the entire study can be seen in Figure 3.
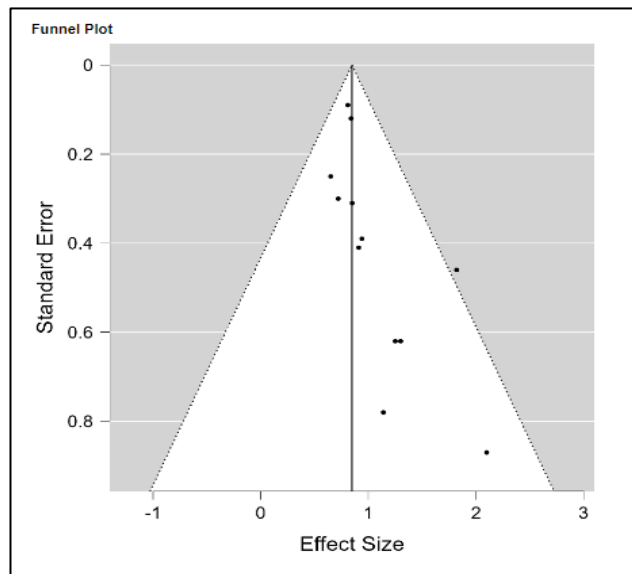
Figure 3. *Funnel Plot Standard Error*

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 6. Egger Test Results

	z	p
sei	1.019	1.292

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 7. Fail Safe Test Results N

	Fail safe N	Target Significance	Observed significance
Rosenthal	589	0.050	< 0.001

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; Cl 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 (Diah et al., 2022; Yıldırım, 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

Abdul Rahman, Ilwandri, Tomi Apra Santosa, Revi Gina Gunawan, Yayat Suharyat, Ringgo Putra6, A. S. (2023). Effectiveness of Problem-Based Learning Model in Science Learning: A Meta- Analysis Study. *JUARA : Jurnal Olahraga*, *8*(2), 713–726.

Aminah, S. (2022). Journal of Technology and Science Education IN TEAM PROJECT-BASED STEM-METACOGNITIVE SKILLS LEARNING. *Journal of Technology and*

Science Education, *12*(2), 397–409.

Anjarwati, D., Juandi, D., Nurlaelah, E., & Hasanah, A. (2022). Studi Meta-Analisis : Pengaruh Model Discovery Learning Berbantuan Geogebra Terhadap Kemampuan Berpikir Kritis Matematis Siswa. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *06*(03), 2417–2427.

Aurora, A., & Effendi, H. (2019). Pengaruh Penggunaan Media Pembelajaran E-learning terhadap Motivasi Belajar Mahasiswa di Universitas Negeri Padang. *JTEV (JURNAL TEKNIK ELEKTRO DAN VOKASIONAL*, *05*(02), 11–16.

Azis, A. (2017). Pengaruh Project Based Learning Terintegrasi Stem Terhadap Literasi Sains , Kreativitas dan Hasil Belajar Peserta Didik Effect of Project-Based Learning Integrated Stem Against Science Literacy , Creativity and Learning Outcomes On Environmental Pollution. *Prosiding Seminar Nasional Biologi Dan Pembelajarannya*, 189–194.

Bahçekapılı, E. (2023). Predicting the secondary school students ' intention to use e-learning technologies. *Research in Learning Technology*, *31*(1063519), 1–13.

Baji, F., Azadeh, F., Sabaghinejad, Z., & Zalpour, A. (2022). Determinants of e-learning acceptance amongst Iranian postgraduate students. *Journal of Global Education and Research*, *6*(2), 181–191.

Balemen, N. (2018). THE EFFECTIVENESS OF PROJECT-BASED LEARNING ON SCIENCE EDUCATION : A META-ANALYSIS SEARCH. *International Online Journal of Education and Teaching (IOJET)*, *5*(4), 849–865.

Berry, L. A., & Kowal, K. B. (2022). Effect of Role-Play in Online Discussions on Student Engagement and Critical Thinking. *Online Learning Journal –*, *26*(3), 4–21.

Biazus, M. D. O., & Mahtari, S. (2022). The Impact of Project-Based Learning (PjBL) Model on Secondary Students ' Creative Thinking Skills. *International Journal of*

Essential Competencies in Education, *1*(1), 38–48.

Bismala, L., Manurung, Y. H., & Siregar, G. (2022). The Impact of E-Learning Quality and Students ' Self -Efficacy Toward the Satisfaction in the Using of E-Learning. *Malaysian Online Journal of Educational Technology*, *10*(2), 141–150.

Candra Eko Purwanto1, Sunyoto Eko Nughoro2, W. (2012). PENERAPAN MODEL PEMBELAJARAN GUIDED DISCOVERY PADA MATERI PEMANTULAN CAHAYA UNTUK MENINGKATKAN BERPIKIR KRITIS Info Artikel Abstrak. *Unnes Physics Education Journal*, *1*(1).

Chusni, M. M., Saputro, S., Surant, S., & Rahardjo, S. B. (2022). Enhancing Critical Thinking Skills of Junior High School Students through Discovery-Based Multiple Representations Learning Model. *International Journal of Instruction*, *15*(1), 927–945. https://doi.org/10.29333/iji.2022.15153a

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences Second Edition*. LAWRENCE ERLBAUM ASSOCIATES,.

Dahliana, P., & Khaldun, I. (2018). Pengaruh Model Guided Discovery Terhadap Kemampuan Berpikir Kritis Peserta didik. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *06*(06), 101–106. https://doi.org/10.24815/jpsi.v6i2.12477

Dharma Ferry, Tomi Apra Santosa, D. K. (2019). Pengetahuan Mahasiswa Institut Agama Islam Negeri Kerinci Tentang Teori Asal Usul Manusia Dharma. *Bioeduca: Journal of Biology Education*, *1*(1), 12–17.

Diah, H. R., Dayurni, P., Evasufi, L., & Fajari, W. (2022). Meta-Analysis Study : The Effect of Android-Based Learning Media on Student Learning Outcomes. *INTERNATIONAL JOURNAL OF ASIAN EDUCATION*, *3*(4), 253–263.

Elfira, I., & Santosa, T. A. (2023). Literature Study : Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555

Farizi et al. (2019). The Effect of the Challenge Based Learning Model on Critical Thinking Skills and Learning Outcomes. *Anatolian Journal of Education*, *4*(1), 13–22. http://e-aje.net/images/dosyalar/aje_2019_1_2.pdf

Fikriyatii, A., Surabaya, U. N., Agustini, R., Surabaya, U. N., Sutoyo, S., Surabaya, U. N., Planning, H. E., & Board, C. (2022). ritical thinking cycle model to promote critical thinking disposition and critical thinking skills of pre-service science teache. *Cypriot Journal of Educational Sciences*, *17*(1), 120–133.

Fradila, E., Razak, A., Santosa, T. A., Arsih, F., & Chatri, M. (2021). Development Of E-Module-Based Problem Based Learning (PBL) Applications Using Sigil The Course Ecology And Environmental Education Students Master Of Biology. *International Journal of Progressive Sciences and Technologies (IJPSAT)*, *27*(2), 673–682.

Gürler, S. A., Kaplan, O., Gürler, A., Steam, O. A. T., & Thinking, C. (2023). *Attitudes Towards STEAM , Critical Thinking Disposition and Decision- Making Skills : Mediation and Gender Moderation To cite this article : Attitudes Towards STEAM , Critical Thinking Disposition and Decision- Making Skills : Mediation and Gender Moderation*.

Hamengkubuwono et al. (2016). The Effect of Teacher Collaboration as the Embodiment of Teacher Leadership on Educational Management Students' Critical Thinking Skills. *European Journal of Educational Research*, *11*(3), 1315–1326.

Hariyanto, Amin, M., Mahanal, S., & Rohman, F.

(2022). Analyzing the Contribution of Critical Thinking Skills and Social Skills on Students' Character By Applying Discovery Learning Models. *International Journal of Education and Practice*, *10*(1), 42–53. https://doi.org/10.18488/61.v10i1.2907

Hasnan, S. M., & Fitria, Y. (2020). Pengaruh Penggunaan Model Discovery Learning Dan Motivasi Terhadap Kemampuan Berpikir Kritis Peserta Didik Sekolah Dasar. *JURNAL BASICEDU*, *4*(2), 239–249.

Heba Bani Issa1, A. K. (2021). The Effect of Using Project Based Learning on Improving the Critical Thinking among Upper Basic Students from Teachers ' Perspectives. *Pegem Journal of Education and Instruction*, *11*(2), 52–57. https://doi.org/10.14527/pegegog.2021.00

Ichsan, Tomi Apra Santosa, Ilwandri, Aulia Sofianora, U. Y. (2022). Efektivitas Evaluasi Model CIPP Dalam Pembelajaran IPA di Indonesia : Meta- Analisis. *Jurnal Pendidikan Dan Konseling*, *5*(2), 1349–1358.

Jagantara, I. M. W., Adnyana, P. B., Luh, N., Manik, P., Studi, P., Ipa, P., & Pascasarjana, P. (2014). (PROJECT BASED LEARNING) TERHADAP HASIL BELAJAR BIOLOGI DITINJAU DARI GAYA BELAJAR SISWA SMA. *E-Journal Program Pascasarjana Universitas Pendidikan Ganesha*, *4*(3), 1–13.

Kaçar, T., Terzi, R., Arıkan, İ., & Kırıkçı, A. C. (2021). The Effect of Inquiry-Based Learning on Academic Success : A Meta-Analysis Study. *International Journal of Education & Literacy Studies*, *9*(2), 15–23.

Listiqowati, I. et al. (2022). The Impact of Project-Based Flipped Classroom (PjBFC) on Critical Thinking Skills. *International Journal of Instruction*, *15*(3), 853–868.

M. Karim , Syafrul Antoni2, Karlini Oktarina3, T.

A. S. (2023). The Effect of Teacher Professionalism in Islamic Religious Education in the Era of Society 5.0 in Indonesia: A Meta-Analysis. *Jurnal Pendidikan Dan Konseling*, *5*(2), 1349–1358.

Mahfudz, M., Sukarno, S., & Info, A. (2023). The effect of ex-add learning techniques on critical thinking skills and pedagogic competence of Islamic education students. *Journal of Education and Learning (EduLearn)*, *17*(2), 221–228. https://doi.org/10.11591/edulearn.v17i2.20782

Merris, D., Sari, M., & Prasetyo, Y. (2021). Project-Based-Learning on Critical Reading Course to Enhance Critical Thinking Skills. *Studies in English Language and Education*, *8*(2), 442–456.

Mursid, R., Saragih, A. H., & Hartono, R. (2022). The Effect of the Blended Project-based Learning Model and Creative Thinking Ability on Engineering Students' Learning Outcomes. *International Journal of Education in Mathematics, Science and Technology*, *10*(1), 218–235. https://doi.org/10.46328/ijemst.2244

Mutakinati, L., & Anwari, I. (2018). ANALYSIS OF STUDENTS ' CRITICAL THINKING SKILL OF MIDDLE SCHOOL THROUGH STEM EDUCATION PROJECT-BASED LEARNING. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 54–65. https://doi.org/10.15294/jpii.v7i1.10495

Nawangsari, N. S., Pujiastuti, P., & Gularso, D. (2022). The effect of project-based learning model on PGSD s tudents ' critical thinking skill. *Jurnal Prima Edukasia*, *10*(1), 19–27.

Niswara, R., Muhajir, M., & Untari, M. F. A. (2019). Pengaruh model project based learning terhadap high order thinking skill. *Mimbar PGSD Undiksha*, *7*(2), 85–90.

Nurtamam, M. E., Santosa, T. A., Aprilisia, S., Rahman, A., & Suharyat, Y. (2023). Meta-analysis : The Effectiveness of Iot-Based Flipped Learning to Improve Students ' Problem Solving Abilities. *Edumaspul :Jurnal Pendidikan*, *7*(1), 1491–1501.

Occe Luciana1*, Tomi Apra Santosa2, Agus Rofi'i3, Taqiyuddin4, B. N. (2023). Meta-analysis: The effect of problem-based learning on students' critical thinking skills. *Edumaspul: Jurnal Pendidikan*, *7*(2), 2058–2068. https://doi.org/10.1063/1.5139796

Putra, M., Rahman, A., Suhayat, Y., Santosa, T. A., & Putra, R. (2023). The Effect of STEM-Based REACT Model on Students ' Critical Thinking Skills : A Meta-Analysis Study. *LITERACY : International Scientific Journals Of Social, Education and Humaniora*, *2*(1), 207–217.

Rahman, A., Santosa, T. A., Suharyat, Y., & Aprilisia, S. (2023). The Effectiveness of AI Based Blended Learning on Student Scientific Literacy : *LITERACY : International Scientific Journals Of Social, Education and Humaniora*, *2*(1), 141–150.

Razak, A., Santosa, T. A., Lufri, & Zulyusri. (2021). Meta-Analisis: Pengaruh HOTS (Higher Order Thinking Skill) terhadap Kemampuan Literasi Sains dan Lesson Study Siswa pada Materi Ekologi dan Lingkungan pada Masa Pandemi Covid-19. *Bioedusiana: Jurnal Pendidikan Biologi*, *6*(1), 79–87.

Ristanto, R. H., Ahmad, A. S., & Komala, R. (2022). Critical thinking skills of environmental changes: A biological instruction using guided discovery learning-argument mapping (gdl-am). *Participatory Educational Research*, *9*(1), 173–191. https://doi.org/10.17275/per.22.10.9.1

Rochmawati, A., & Ridlo, S. (2020). Analysis of 21 st Century Skills of Student on Implementation Project Based Learning and Problem Posing Models in Science Learning. *Journal of Primary Education*, *9*(1), 58–67.

Santosa, T. A., Razak, A., Arsih, F., & Sepriyani, E. M. (2021). Meta-Analysis : Science Learning Based on Local Wisdom Against Preserving School Environments During the Covid-19 Pandemic. *Journal of Biology Education*, *10*(2), 244–251.

Santosa, T. A., Sepriyani, E. M., Lufri, L., & Zulyusri, Z. (2021). Meta-Analysis: Penggunaan Modul Berbasis Hots Pada Materi Ekologi Dan Lingkungan Di Sma. *Jurnal Eduscience*, *8*(1), 53–56. https://doi.org/10.36987/jes.v8i1.1976

Santosa, T. A., Sepriyani, E. M., & Razak, A. (2021). Analisis E-Learning Dalam Pembelajaran Evolusi Mahasiswa Pendidikan Biologi Selama Pandemi Covid-19. *Jurnal Edumaspul*, *5*(1), 66–70.

Saripudin, A., Haryani, S., & Wardani, S. (2015). Characterized project based learning to improve critical thinking skill. *International Conference on Mathematics, Science, and Education*, *2015*(Icmse).

Smolinski, P. R., Szostakowski, M., & Winiarski, J. (2023). E-Learning Software : Comparing the use Behavior Among Academicians and Schoolteachers. *The Electronic Journal of E-Learning*, *21*(2), 98–109.

Sofianora, A., Suharyat, Y., & Santosa, T. A. (2023). *PENGARUH PROFESIONALITAS GURU MATEMATIKA DALAM MENINGKATKAN KOMPETENSI SISWA ERA REVOLUSI INDUSTRI 5 . 0 DI INDONESIA : SEBUAH META-ANALISIS*. *10*(2).

Suharyat, Y., Santosa, T. A., Aprilisia, S., & Yulianti, S. (2022). International Journal of Education and Literature (IJEL) Meta-Analysis Study : The Effectiveness of Problem Solving Learning in Science Learning in Indonesia. *International Journal of Education and Literature (IJEL) Amik Veteran Porwokerto*, *1*(3), 6–13.

Suharyat, Y., Santosa, T. A., & Satria, E. (2023). The Effectiveness of STEM-Based Learning in Teaching 21 st Century Skills in Generation Z Student in Science Learning : A. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 160–166. https://doi.org/10.29303/jppipa.v9i1.2517

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21. https://doi.org/10.15294/jpii.v9i1.21754

Suparman, Juandi, D., & Tamur, M. (2021). Review of problem-based learning trends in 2010-2020: A meta-analysis study of the effect of problem-based learning in enhancing mathematical problem-solving skills of Indonesian students. *Journal of Physics: Conference Series*, *1722*(1). https://doi.org/10.1088/1742-6596/1722/1/012103

Supratman et al. (2021). The Effect Size of Different Learning on Critical and Creative Thinking Skills of Biology Students. *International Journal of Instruction*, *14*(3), 187–206.

Supriyadi, A., Suharyat, Y., Santosa, T. A., & Sofianora, A. (2023). The Effectiveness of STEM-Integrated Blended Learning on Indonesia Student Scientific Literacy : A Meta-analysis. *International Journal of Education and Literature (IJEL)*, *2*(1), 41–48.

Suryono, W., Haryanto, B. B., Santosa, T. A., Suharyat, Y., & Sappaile, B. I. (2023). The Effect of The Blended Learning Model on Student Critical Thinking Skill : Meta-analysis. *Edumaspul - Jurnal Pendidikan*, *7*(1), 1386–1397.

Suteja, S., & Setiawan, D. (2021). Students ' Critical Thinking and Writing Skills in Project-Based Learning. *International Journal of Educational Qualitative Quantitative Research (IJE-QQR)*, *1*(1), 16–22. https://doi.org/10.58418/ijeqqr.v1i1.5

Syawaludin, A., Prasetyo, Z. K., Safruddin, C., &

Jabar, A. (2022). The Effect of Project-based Learning Model and Online Learning Settings on Analytical Skills of Discovery Learning , Interactive Demonstrations , and Inquiry Lessons. *Journal of Turkish Science Education*, *19*(2), 608–621.

Trisdiono, H., Siswandari, S., & Suryani, N. (2019). Development of Multidisciplinary Integrated Project-Based Learning Model To Improve Critical Thinking and Cooperation Skills. *JPI*, *8*(1), 9–20. https://doi.org/10.23887/jpi-undiksha.v8i1.17401

Tuaputty, H., Alimudi, S., & Irene, I. (2023). Project-based learning using a laboratory approach on learning outcomes and critical thinking in marine biology. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(1), 103–114.

Ucar, D., & Yilmaz, S. (2023). PRE-SERVICE SCIENCE TEACHERS ' E-LEARNING STYLES ISSN 1648-3898 ISSN 2538-7138. *Journal of Baltic Science Education*, *22*(1), 167–181.

Uyar, A. (2023). Exploring the s tudents' attitudes towards e-learning at territory level: a f ocus on Türkiye. *International Journal of Curriculum and Instruction*, *15*(2), 1327–1353.

Vidergor, H. E., & Academic, G. (2022). *Problem-based Learning Problem-based Learning Effects of Innovative Project-Based Learning Model on Students ' Knowledge Acquisition , Cognitive Abilities , and Personal Competences*. *16*(1).

Wanglang, C., & Chatwattana, P. (2023). The Project-Based Learning Model Using Gamification to Enhance 21 st Century Learners in Thailand. *Journal of Education and Learning*, *12*(2), 99–105. https://doi.org/10.5539/jel.v12n2p99

Wayan Santyasa, I., Agustini, K., & Eka Pratiwi, N. W. (2021). Project based e-learning and academic procrastination of students in learning chemistry. *International Journal of Instruction*, *14*(3), 909–928. https://doi.org/10.29333/iji.2021.14353a

Yıldırım, N. (2022). Argumentation-Based Teaching in Science Education: Meta-Analysis. *Education Quarterly Reviews*, *5*(2), 226–237. https://doi.org/10.31014/aior.1993.05.02.483

Yusuf, F. A. (2023). International Journal of Educational Methodology Meta-Analysis : The Influence of Local Wisdom-Based Learning Media on the Character of Students in Indonesia. *International Journal of Educational Methodology*, *9*(1), 237–247.

Zhenchenko, M., Melnyk, O., Prykhoda, Y., & Zhenchenko, I. (2022). Ukrainian E-Learning Platforms for Schools : Evaluation of Their Functionality. *International Review of Research in Open and Distributed Learning*, *23*(2), 1–15.

Zulkifli Zulkifli, Agus Supriyadi, Erwinsyah Satria, & Tomi Apra Santosa. (2022). Meta-analysis: The Effectiveness of the Integrated STEM Technology Pedagogical Content Knowledge Learning Model on the 21st Century Skills of High School Students in the Science Department. *Psychology, Evaluation, and Technology in Educational Research*, *1*(2), 68–76. https://doi.org/10.55606/ijel.v1i2.