

Systematic Analysis of The Implementation of Problem Based Learning (PBL) and Project Based Learning (PjBL) Models in Science and Mathematics Education in Indonesia

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Abstract: This systematic literature review analyzes the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) models in Science and Mathematics education within Indonesia. Using the Systematic Literature Review (SLR) method guided by PRISMA guidelines, this study examined 21 articles from Sinta-accredited journals (2020-2025). The findings indicate that the PBL model is highly effective in enhancing students' critical thinking skills, problem-solving abilities, and cognitive learning outcomes. Conversely, the PjBL model demonstrates a more significant impact on fostering creativity, collaboration, and 21st-century skills. A synthesis of the results reveals that both models support active and contextual learning, aligning with the principles of Indonesia's Merdeka Curriculum and the Pancasila Student Profile. This study concludes that PBL and PjBL offer distinct yet complementary benefits. For optimal implementation, teacher training and contextual adaptation are crucial. The integration of these models presents a strategic approach to advancing Science and Mathematics education by developing a generation that is intellectually competent, innovative, and collaborative.

Keywords: Merdeka Curriculum; Problem Based Learning; Project Based Learning; Science Education; Mathematics Education; Systematic Literature Review

Introduction

A paradigm shift in 21st century education has created a demand for competencies in Higher Order Thinking Skills (HOTS), creativity, communication, and collaboration. In this context, Science and Mathematics education plays a crucial role in fostering critical, innovative, and technologically adaptive individuals. The implementation of student-centered approaches, particularly Problem-Based Learning (PBL) and Project-Based Learning (PjBL), is widely recognized as an effective means to develop these competencies, leading to their integration within frameworks like the Merdeka Curriculum (Paraniti et al., 2024).

Problem Based Learning (PBL) is an instructional approach driven by open-ended, ill-structured problems that simulate real-world challenges. Based on constructivist principles, Problem-Based Learning (PBL) utilizes real-world, ill-structured problems as the initial

stimulus and driver for student-directed inquiry and collaborative knowledge construction (Barrows, 1996; Hmelo-Silver, 2004). This pedagogy redefines the instructor's role from a knowledge transmitter to a facilitator who guides small groups of students as they actively identify their learning needs and strategies to solve complex problems.

Problem-Based Learning (PBL) has been recognized as a highly effective pedagogical approach for fostering scientific creativity by engaging students in authentic, real-world problem-solving scenarios that mirror the processes of scientific inquiry. According to a recent meta-analysis by Pinar et al. (2025), PBL demonstrated a substantial positive impact on scientific creativity, with a large effect size (Hedges' $g = 1.49$), underscoring its role in promoting critical thinking, collaborative inquiry, and innovative solution design. By immersing learners in complex, interdisciplinary challenges, PBL not only enhances their ability to formulate hypotheses and conduct investigations but

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also cultivates the flexible and original thinking essential for addressing modern scientific and technological problems (Pinar et al., 2025). Research in Indonesia supports the effectiveness of both models. Fetriani et al. (2025) found that the implementation of PBL at SDN 3 Muara Belit improved student science learning outcomes by 48%. Kurniawan (2023) also reported an enhancement in student's conceptual understanding of mathematics through PBL. Meanwhile Farhin et al. (2023) demonstrated that PjBL increased elementary school student's creativity in science learning.

PjBL in an innovative student-centered learning approach that engages student in authentic and meaningful project to develop problem solving, critical thinking and collaboration skills. Grounded in constructivist theory, it enables student to actively construct knowledge by connecting subject matter with real world contexts (Bell, 2010 ; Almulla, 2020). This approach not only enhances conceptual understanding but also foster essential 21st century skill for preparing student to face future challenges.

In the context of Science and Mathematics education, PjBL has proven effective in improving student learning outcomes. A study by Güley & Keskinliç (2024) showed that a PjBL based science program significantly enhanced early childhood problem solving skill, with lasting effects. Meanwhile, research by Susanto et al. (2020) confirmed that PjBL in Mathematics not only improved collaborative and critical thinking skill but also fostered a more positive attitude towards the subject, ultimately encouraging deeper learning engagement.

Among the most prominent are Problem-Based Learning (PBL) and Project-Based Learning (PjBL), which are often promoted within national curricula like the Merdeka Curriculum for their student-centered and problem-solving nature (Paraniti et al., 2024). Empirical evidence underscores the effectiveness of the PBL model; for instance, a study by Arfani and Setyasto (2025) demonstrated that a video-assisted PBL model significantly improved students' problem-solving abilities in physics compared to conventional methods. Concurrently, the integration of PjBL with digital tools is also gaining traction, as highlighted in a review by Doyan et al. (2025), which identifies PjBL as a key model for improving generic science skills through technology-enhanced learning like interactive web media. However, despite their recognized potential, the implementation of both PBL and PjBL in real-world classroom settings often encounters obstacles, including difficulties for teachers in designing core activities, conducting diagnostic assessments, and managing time effectively (Paraniti et al., 2024).

Furthermore, several empirical studies on the implementation of innovative learning models such as

PBL and PjBL show a significant impact on improving students' 21st-century skills. Research by Hikmawati (2022) demonstrated that PjBL integrated with scientific article analysis methods successfully improved student learning outcomes with an N-gain value in the medium category, while a study by Wahyudiati and Qurniati (2022) revealed that PjBL not only enhanced critical thinking skills but also the self-efficacy of pre-service chemistry teachers with a contribution of 35%. These findings indicate the great potential of both models in creating contextual and impactful learning, thus requiring more systematic review to provide an evidence-based map for science and mathematics educators and researchers in Indonesia.

Similar finding were revealed by Farhin et al (2023), who investigated local project based PjBL and found a significant increase in students creative thinking abilities. However, several studies also indicate constraints in its implementation. Indarwati et al. (2014) reported that teacher still face difficulties in time management and developing PBL scenarios that are relevant to the student's context. Therefore, this study conducts a systematic review of the implementation of PBL and PjBL in Indonesia to map the trends, effectiveness as well as the obstacles and supporting factor for the application of both models in the context of Science and Mathematics learning.

Method

This study employs the Systematics Literature Review (SLR) method, guided by the preferred reporting items for systematics review and meta-analyses (PRISMA) guidelines. This approach was selected to obtain a comprehensive overview of the implementation of PBL and PjBL models in Science and Mathematics education from 2020 to 2025.

The first stage was data source identification. Articles were gathered from various academic portals such as Google Scholar, springer and SINTA (Science and Technology Index). The keywords used included "Problem Based Learning," "Project Based Learning," "MIPA," "Mathematics," "Science," and "Merdeka Curriculum" The initial search yielded 85 scientific articles.

The second stage was initial screening, which involved reviewing titles and abstracts to ensure relevance to the topic. Articles that were not relevant to the Science and Mathematics learning context, did not utilize PBL or PjBL models, or were published outside the 2020-2025 period were excluded. This initial screening process resulted in 45 articles.

The third stage was the feasibility assessment. Articles were verified based on methodological clarity, journal accreditation status, and full-text availability. As

a result, 28 articles were deemed to meet the eligibility criteria.

The fourth stage, data inclusivity, involved a final selection of 21 articles that fully met all the criteria. The articles utilized originated from various educational levels, ranging from elementary school to higher education, and encompassed diverse methodologies such as Classroom Action Research (CAR), experimental, quasi-experimental, and mixed-methods studies.

Subsequently, a process of data extraction and coding was conducted. Data extracted from each article included the author, year, title, educational level, learning model, research findings, and recommendations. This data was then categorized into four main themes: improvement of learning outcomes, development of critical thinking skills, creativity and innovation, and 21st century skills such as collaboration and communication.

The final stage involved thematic analysis and synthesis of the findings. The analysis was performed by identifying patterns of convergence and divergence across the studies, there by yielding a deeper understanding of the effectiveness and challenges of implementing both models. A thematic synthesis approach was employed to integrate the findings narratively, enabling the formulation of relevant recommendations for Science and Mathematics education in Indonesia.

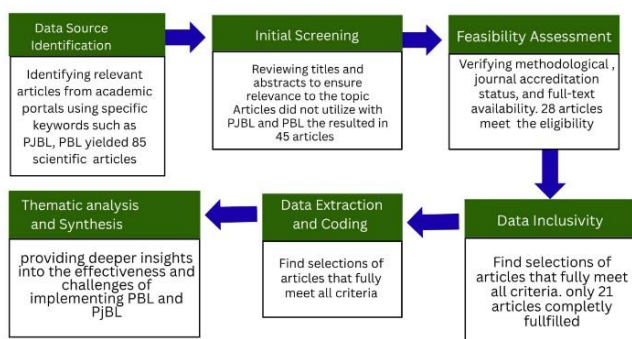


Figure 1. Flowchart of Article Selection Process in the Systematic Literature review

Result and Discussion

Analysis of the 21 articles reveals that the implementation of both PBL and PjBL models has a broad positive impact on Science and Mathematics education across various educational levels. These findings indicate that both inquiry-based learning approaches have been widely adopted and researched, with each offering unique contributions to enhancing the quality of the learning process and student outcomes.

The implementation of PBL has been proven to enhance critical thinking skills and cognitive learning outcomes. Manuaba et al. (2024) reported significant improvements in analytical abilities. A similar finding was reported by Novianti et al. (2020), who observed a rise of up to 30% in elementary school students' learning engagement following PBL implementation. Further strengthening this evidence, research by Wajdi et al. (2022) demonstrated that contextually-based PBL was effective in improving the critical thinking skills of high school students in chemistry. Beyond cognitive aspects, PBL also positively impacts affective factors in learning. Subagio et al. (2021) revealed that the integration of technology, specifically the use of the GeoGebra application within PBL, successfully increased students' interest and achievement in mathematics. This indicates that PBL not only develops intellectual capabilities but also fosters a positive attitude towards Science and Mathematics subjects, which is a crucial component of meaningful learning.

Meanwhile, the PjBL model demonstrated a greater impact on fostering creativity and collaboration. Rehman et al. (2024) found that PjBL effectively encouraged the development of students' collaborative skills in completing mathematics projects. Gunawan (2020) reported that PjBL enhanced students' scientific creativity through the exploration of their local environment, highlighting the strength of this approach in connecting learning to real-world contexts. The effectiveness of PjBL in developing science process skills is also empirically supported. Studies by Nurhidayah et al. (2019) showed an increase of up to 85% in students' science process skills through PjBL implementation. This finding is reinforced by research from Nabila et al. (2025), which affirmed that differentiated PjBL significantly improved elementary school students' numeracy and scientific skills.

Based on the reviewed empirical studies, the implementation of Project Based Learning (PjBL) demonstrates a consistent and significant positive impact on various 21st-century skills essential for science education in Indonesia. The study by Susilawati et al. (2023) developed and validated a smartphone-integrated PjBL media for modern physics, which was deemed highly effective in fostering student creativity and scientific literacy, highlighting the model's capacity to make abstract concepts more accessible and engaging. Complementing this, the research by Wahyudiati & Qurniati (2022) provided experimental evidence that PjBL significantly enhanced pre-service chemistry teachers' self-efficacy and critical thinking skills, accounting for a 35% contribution to these outcomes, thereby underscoring the model's role in building crucial psychological attributes and higher-order thinking. Furthermore, Hikmawati (2022)

demonstrated that applying PjBL with a scientific article analysis method successfully improved student learning outcomes with a moderate N-gain, showcasing its versatility and effectiveness even in online learning settings. Collectively, these findings solidify the position of PjBL, alongside Problem Based Learning (PBL), as a powerful pedagogical model in MIPA education, capable of addressing the need for innovative, student-centered learning that develops both cognitive and soft skills required in the modern era.

Based on the ANOVA analysis presented in this study, the effectiveness of PjBL in mathematics yielded limited and varied results depending on the variable measured. Although no significant differences were found between PjBL and traditional classes for the majority of learning environment scales and student outcomes, the analysis revealed that students in PjBL classes perceived a significantly less positive learning environment on the equity scale ($F = 4.60, p < 0.05$) and demonstrated significantly lower Achievement ($F = 11.15, p < 0.01$) compared to their peers in traditional classes (Rijken & Fraser, 2024). These findings indicate that while PjBL may offer a different learning experience, its implementation in this specific context was not universally more effective than the traditional approach, particularly in ensuring equity and fostering comparable academic attainment.

Table 1. Average item mean, average item standard deviation and difference between instructional method (Cohen’s d effect and ANOVA results) for each learning environment, enjoyment, efficacy and achievement scale.

Scale	Item mean		Item SD		Difference	
	Project	Non-project	Project	Non-project	d	F
Learning environment						
Student cohesiveness	4.08	4.10	0.67	0.63	-0.03	0.11
Teacher support	3.60	3.70	0.95	0.81	-0.11	1.04
Involvement	3.27	3.28	0.79	0.86	-0.01	0.03
Investigation	3.39	3.48	0.79	0.90	-0.11	0.88
Task orientation	4.10	4.01	0.71	0.80	0.12	0.18
Cooperation	3.97	3.97	0.77	0.86	0.00	0.06
Equity	3.75	3.99	0.97	0.87	-0.26	4.60*
Student outcomes						
Enjoyment	3.05	3.00	1.06	1.07	0.05	0.07
Academic efficacy	3.19	3.14	0.87	0.85	0.06	0.13
Achievement	5.99	6.41	0.96	0.97	-0.44	11.15**

N = 192 project and 92 non-project students

* $p < 0.05$ ** $p < 0.01$

Percentage achievement scores were divided by 10 to provide a score range similar to other scales

Based on the study by Al-Qoyyim et al. (2024), which demonstrated that the implementation of video-assisted Physics Problem-Based Learning (PBL) significantly enhances students' problem-solving abilities in static fluid topics compared to conventional methods. Aligned with this effectiveness in the domain of instructional material development, Anggraeni et al. (2022) also found that a PBL-based Science E-Module on

global warming was rated highly valid by experts as a feasible medium for improving students' critical thinking skills. These two studies reinforce the argument that the adaptability of the PBL model to digital media innovations is a crucial strategy for optimizing science education in Indonesia to address 21st-century skill challenges.

Based on the meta-analysis conducted by Pinar et al. (2025), it can be concluded that scientific problem-solving approaches – particularly Project-Based Learning (PjBL), Problem-Based Learning (PBL), STEM/STEAM contexts, and Inquiry Based Learning (IBL) are significantly effective in fostering students' scientific creativity. Key findings reveal that PjBL and PBL yielded the largest impacts (with effect sizes of $g = 2.10$ and $g = 1.49$, respectively), underscoring the superiority of authentic, collaborative, and iteratively-processed project- and problem-based approaches in stimulating innovative thinking. Although high heterogeneity was observed among the analyzed studies, along with indications of publication bias, the overall results provide strong evidence that engaging students in the stages of the scientific method – such as problem formulation, experimental design, and evaluation – serves as a fundamental foundation for developing creative capacities in science contexts. Therefore, integrating these approaches into science education curricula is highly recommended to prepare students for complex 21st-century challenges.

Table 2. Moderator and subgroup analyses of scientific problem solving approaches

Moderator	Subgroup	k	Test for Effect			Test for Heterogeneity			
			Hedges' g	Std error	Variance	95% CI	Q-value	Df(Q)	p-value
Approaches	IBL	3	0.43	0.24	0.19	-0.62, 1.48	9.28	4	0.000**
	PjBL	4	2.1	1.02	3.19	-1.15, 5.34			
	PBL	2	1.49	0.6	0.63	-6.11, 9.09			
	STEM/STEM	6	1.21	0.5	1.11	-0.06, 2.49			
	Combination*	6	1.43	0.31	0.44	0.64, 2.22			
Educational Level	Primary	8	1.22	0.23	0.45	0.68, 1.75	5.63	2	0.000**
	Secondary	10	0.93	0.32	0.56	0.22, 1.65			
	College	3	3.21	0.91	2.14	-0.69, 7.11			
Science Domain	Biology	3	1.03	0.62	1.06	-1.62, 3.68	0.27	3	0.000**
	Physics	4	1.32	0.4	0.35	0.06, 2.58			
	Science	5	1.09	0.31	0.38	0.22, 1.95			
Duration of Intervention	STEM/STEAM	8	1.21	0.39	0.87	0.28, 2.14	6.53	3	0.000**
	0-6 weeks	9	1.85	0.5	1.02	0.70, 2.99			
	7-12 weeks	8	1.05	0.26	0.52	0.43, 1.68			
	More than 13 weeks	2	1.28	0.84	1.33	-0.41, 11.96			
Learning Format	Not reported	2	0.35	0.35	0.19	-4.11, 4.80	2.32	2	0.000**
	Collaborative	14	1.51	0.35	0.94	0.74, 2.25			
	Individual	3	1.32	0.7	1.5	-1.71, 4.35			
	Combination*	4	0.83	0.28	0.21	-0.05, 1.72			

Note. *A combination of TPS pedagogical approaches (i.e., PjBL and STEM) or learning format (i.e., collaborative and individual activities); **Significant at $p < 0.05$

Both models possess unique yet complementary roles within the Science and Mathematics learning ecosystem. PBL tends to be more robust in building analytical thinking and logical reasoning through structured problem-solving, whereas PjBL excels in nurturing innovative and collaborative abilities through more open-ended project completion. The collective findings from various studies suggest that combining elements from both models can create a balanced learning experience that develops both cognitive and affective domains.

From an implementation standpoint, key success factors include teacher readiness, facility support, and thorough instructional planning. Common challenges involve time constraints for project completion and the availability of supporting resources. However, several studies conclude that with adequate teacher training and contextually tailored application, both models can be implemented effectively across diverse school conditions.

In conclusion, both PBL and PjBL have proven to be effective instructional approaches for enhancing various competencies in Science and Mathematics education. The choice between these models should be based on the characteristics of the subject matter, learning objectives, and students' learning context. These two models offer distinct yet equally meaningful pathways for transforming Science and Mathematics learning into a more relevant, engaging, and impactful experience for developing 21st-century competencies.

Conclusion

Based on this journal study, it can be concluded that the implementation of Problem-Based Learning (PBL) and Project-Based Learning (PjBL) significantly enhances the quality of Science and Mathematics education in Indonesia. PBL proves superior in developing critical thinking skills, problem-solving abilities, and cognitive learning outcomes, while PjBL is more effective in fostering student creativity, collaboration, and social responsibility. These two models are complementary and support active, contextual learning aligned with the Pancasila Student Profile and the Merdeka Curriculum. For optimal results, adequate teacher training, contextual adaptation, and the integration of elements from both models are essential to create a balanced and meaningful learning experience for students.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open*, 10(3), 1-15. <https://doi.org/10.1177/2158244020938702>
- Al-Qoyyim, T. M., Wahyudi, Gunawan, & Doyan, A. (2024). The influence of problem based learning model assisted by video on student's problem-solving skills in static fluid material. *Journal of Science and Science Education*, 5(1), 22-30. <https://doi.org/10.29303/jossed.v5i1.7382>
- Anggraeni, N., Rahardjo, S. B., & Harlita. (2022). The validity of problem based learning (PBL)-based global warming e-module. *Jurnal Penelitian Pendidikan IPA*, 8(5), 2335-2340. <https://doi.org/10.29303/jppipa.v8i5.1934>
- Arfani, F., & Setyasto, N. (2025). The Effectiveness of the Problem-Based Learning Model Assisted by Augmented Reality on Learning Outcomes of Natural and Social Sciences in Solar System Material. *Jurnal Penelitian Pendidikan IPA*, 11(2), 1070-1078. <https://doi.org/10.29303/jppipa.v11i2.10317>
- Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning*, 1996(68), 3-12. <https://doi.org/10.1002/tl.37219966804>
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39-43. <https://doi.org/10.1080/00098650903505415>
- Doyan, A., Susilawati, Harjono, A., Annam, S., Ikhsan, M., Ardianti, N. R., & Hakim, S. (2025). A Review: Improving Generic Science Skills through Interactive Web-Based Modern Physics Learning Media with PjBL Model. *Jurnal Penelitian Pendidikan IPA*, 11(3), 76-85. <https://doi.org/10.29303/jppipa.v11i3.10439>
- Farhin, N., Setiawan, D., & Waluyo, E. (2023). Peningkatan hasil belajar siswa sekolah dasar melalui penerapan "project based-learning". *JPTK*, 1*(2). <https://doi.org/10.61650/jptk.v1i2.144>
- Fetriani, M., Charli, L., & Yuneti, A. (2025). Penerapan model pembelajaran problem based learning dalam pelajaran IPA siswa kelas V SDN 3 Muara

- Beliti. *LJSE*, 2(3). <https://doi.org/10.55526/ljse.v2i3.5216>
- Güley, B., & Keskinclı, A. (2024). The effect of project approach-based science education program on problem-solving skills of preschool children. *Humanities and Social Sciences Communications*, 11(1), 1-9. <https://doi.org/10.1057/s41599-024-03444-0>
- Gunawan, B., Relmasira, S. C., & Asri, A. T. (t.t.). Penerapan model pembelajaran project based learning untuk meningkatkan hasil belajar IPA dan kemampuan berfikir kreatif siswa kelas V SD. *Jurnal Basicedu*, 4(1). <https://doi.org/10.31004/basicedu.v4i1.323>
- Hikmawati, H. (2022). Application of Project Based Learning with Scientific Article Analysis Method to Improve Student Learning Outcomes in Education Profession Courses. *Journal of Science and Science Education*, 3(2), 115-121. <https://doi.org/10.29303/jossed.v3i2.2452>
- Indarwati, D., Wahyudi, & Ratu, N. (2014). Peningkatan kemampuan pemecahan masalah matematika melalui penerapan problem based learning untuk siswa kelas V SD. *Scholaria*, 30(1), 17-27. <https://doi.org/10.24246/j.sw.2014.v30.i1.p17-27>
- Kurniawan, B., Dwikoranto, & Marsini. (2023). Implementasi problem based learning untuk meningkatkan pemahaman konsep siswa: Studi pustaka [Implementation of problem based learning to improve students' concept understanding: Literaturereview]. *HAFECSPPOST*, 2(1). <https://doi.org/10.58362/hafecspost.v2i1.28>
- Manuaba, I. B. A. P., Yi-No, & Wu, C.-C. (2024). The effectiveness of problem based learning in improving critical thinking, problem-solving and self-directed learning in first-year medical students: A meta-analysis. *PLoS ONE*, 19(5), e0303724. <https://doi.org/10.1371/journal.pone.0303724>
- Novianti, A., Bentri, A., & Zikri, A. (2020). Pengaruh penerapan model problem based learning (PBL) terhadap aktivitas dan hasil belajar siswa pada pembelajaran tematik terpadu di sekolah dasar. *Jurnal Basicedu*, 4(1), 234-244. <https://doi.org/10.31004/basicedu.v4i1.323>
- Nurhidayah, I. J., Wibowo, F. C., & Astra, I. M. (2021). Project Based Learning (PjBL) Learning Model in Science Learning: Literature Review. *Journal of Physics: Conference Series*, 2019, 012043. <https://doi.org/10.1088/17426596/2019/1/012043>
- Paraniti, A. A. I., Redhana, I. W., Suardana, I. N., & Suma, K. (2024). A Novel Learning Model, Integration of Challenge-Based and Differentiated Learning: A Preliminary Study. *Jurnal Penelitian Pendidikan IPA*, 10(3), 1299-1308. <https://doi.org/10.29303/jppipa.v10i3.5245>
- Pinar, F. I. L., Panergayo, A. A. E., Sagcal, R. R., Acut, D. P., Roleda, L. S., & Prudente, M. S. (2025). Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: a meta-analysis. *Disciplinary and Interdisciplinary Science Education Research*, 7(18). <https://doi.org/10.1186/s43031-025-00137-9>
- Rijken, M., & Fraser, B. (2024). Project Based Learning for enhancing collaboration and motivation in mathematics learning. *Jurnal Pendidikan Matematika Indonesia*, 5(4), 205-216. <https://garuda.kemdikbud.go.id/documents/detail/3955527>
- Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, 10(11), e39988. <https://doi.org/10.1016/j.heliyon.2024.e39988>
- Rijken, P. E., & Fraser, B. J. (2024). Effectiveness of project-based mathematics in first-year high school in terms of learning environment and student outcomes. *Learning Environments Research*, 27, 241-263. <https://doi.org/10.1007/s10984-023-09477-7>
- Susanto, E., Susanta, A., & Rusdi. (2020). Efektivitas project based learning terhadap kemampuan pemecahan masalah dan berpikir kritis mahasiswa. *ThufuLA: Jurnal Inovasi Pendidikan Guru Madrasah Ibtidaiyah*, 5(1). <https://doi.org/10.31949/th.v5i1.2219>
- Susilawati, S., Doyan, A., Rokhmat, J., & Muliyadi, L. (2023). Analysis Validation of Modern Physics Learning Media Based on Smartphone Integrated Project Based Learning to Improve Students' Creativity and Scientific Literacy. *Jurnal Penelitian Pendidikan IPA*, 9(10), 7888-7892. <https://doi.org/10.29303/jppipa.v9i10.5404>
- Subagio, L., Karnasih, I., & Irvan, I. (2021). Meningkatkan motivasi belajar siswa dengan menerapkan model discovery-learning dan problem-based-learning berbantuan geogebra. *Jurnal Pendidikan Matematika Raflesia*, 6(2). <https://doi.org/10.33369/jpmr.v6i2.15733>
- Wahyudiati, D., & Qurniati, D. (2022). The Effect of Project-Based Learning on Pre-Service Chemistry Teachers' Self-Efficacy and Critical Thinking

- Skills. *Jurnal Penelitian Pendidikan IPA*, 8(5), 2307–2311. <https://doi.org/10.29303/jppipa.v8i5.1834>
- Wajdi, M. (2022). Pengaruh model pembelajaran problem based learning (PBL) terhadap kemampuan berpikir kritis siswa pada konsep sistem peredaran darah manusia. *Hybrid: Jurnal Pendidikan Dan Pembelajaran Sains*, 1(1), 19–26. <https://doi.org/10.51574/hybrid.v1i1.540>