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Development of Augmented Reality Media Integrated with Project-Based Learning to Improve Elementary School Students' Creative Thinking Skills

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Keywords:	Abstract
keyword 1; Augmented Reality	<i>This study aims to develop Augmented Reality (AR) media integrated with Project-Based Learning (PjBL) and examine its feasibility, practicality, and effectiveness in improving elementary school students' creative thinking skills. The research employed a research and development (R&D) method using a simplified development model consisting of analysis, design, development, implementation, and evaluation stages. The subjects of the study were elementary school students who participated in the learning process using the developed AR media. The data were collected through expert validation questionnaires, student and teacher response questionnaires, and creative thinking skills tests (pre-test and post-test). The data were analyzed descriptively using quantitative and qualitative analysis techniques. The feasibility of the media was determined through expert validation, practicality was measured based on student and teacher responses, and effectiveness was analyzed using pre-test and post-test results along with N-gain scores. The results showed that the AR media obtained a very good validity score of 4.45, indicating that it is highly feasible for use in learning. The practicality results showed positive responses from students (88%) and teachers (91%), categorized as very practical. Furthermore, the effectiveness test showed an increase in students' creative thinking skills, with an average pre-test score of 62.30 and post-test score of 84.75, and an N-gain value of 0.60 in the moderate category. These findings indicate that the developed AR media is</i>
keyword 2; Project-Based Learning	
keyword 3 creative	
thinking skills	

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feasible, practical, and effective in improving students' creative thinking skills. In conclusion, the integration of Augmented Reality with Project-Based Learning provides an innovative and effective learning approach that enhances student engagement and supports the development of creative thinking skills in elementary education.

INTRODUCTION

Background of the Study

The rapid advancement of digital technology in recent years has significantly transformed the educational landscape. This transformation requires the integration of innovative learning approaches that align with 21st-century competencies, including creativity, critical thinking, collaboration, and communication. Among these, creative thinking is a fundamental skill that should be developed from the elementary school level, as it enables students to generate original ideas, solve problems flexibly, and adapt to changing environments (Doğan et al., 2025).

However, learning practices in elementary schools are still predominantly teacher-centered and rely on conventional instructional methods. Such practices limit students' opportunities to actively participate, explore ideas, and engage in meaningful learning experiences. Consequently, students' creative thinking skills remain underdeveloped. Recent studies indicate that the lack of interactive learning media and the limited implementation of innovative instructional models contribute significantly to this issue (K. Perayani & I.W. Rasna, 2022).

To address this problem, Project-Based Learning (PjBL) has been widely recognized as an effective instructional model for fostering creative thinking. PjBL encourages students to engage in authentic tasks, explore solutions, and produce tangible outcomes. At the same time, the integration of emerging technologies, such as augmented reality (AR), has shown promising results in enhancing student engagement, motivation, and conceptual understanding through interactive and immersive experiences.

In the modern educational paradigm, 21st-century learning demands a fundamental shift from traditional knowledge transmission toward the cultivation of high-order cognitive capabilities. Among these capabilities, creative thinking serves as a vital foundation for young learners, enabling them to construct original solutions, synthesize diverse perspectives, and adapt to unpredictable future challenges. Fostering creativity at the elementary school level is particularly crucial, as children in this developmental stage possess high innate curiosity and dynamic spatial imagination. Without deliberate pedagogical strategies designed to nurture these traits, students' natural creative potential risks being suppressed by rigid instructional frameworks.

Despite the recognized importance of creative thinking, conventional classroom instruction in elementary education frequently falls short of providing conducive learning

environments. Traditional teaching practices often rely heavily on memorization, textbook-centric routines, and passive listening, which treat students as passive consumers of information rather than active creators. This instructional rigidity contributes to low levels of student engagement, poor problem-solving flexibility, and a lack of confidence when expressing novel ideas. Consequently, there is an urgent need to reform elementary classroom practices by introducing dynamic, interactive, and learner-centered instructional models.

Project-Based Learning (PjBL) has emerged as a promising pedagogical strategy to address these traditional instructional limitations. By engaging students in meaningful, real-world projects, PjBL transforms the classroom into a collaborative workspace where learners systematically plan, execute, and evaluate authentic tasks. The iterative syntax of PjBL—ranging from framing fundamental questions to assessing project outcomes—inherently requires students to exercise creative problem-solving, fluency, and elaboration. However, the successful implementation of PjBL in elementary settings often encounters obstacles when dealing with complex or abstract concepts that young learners struggle to visualize through physical materials alone.

To overcome these visual and conceptual barriers in PjBL, the integration of advanced instructional technology, specifically Augmented Reality (AR), offers a powerful solution. Augmented Reality enhances the physical world by overlaying interactive 3D digital artifacts into the student's real-time environment, making abstract structures tangible and easy to manipulate. When embedded within project activities, AR technology acts as an intuitive cognitive scaffold that stimulates spatial reasoning and ignites imaginative thinking. This multi-sensory learning experience allows students to explore geometric, scientific, and spatial concepts from multiple angles, directly inspiring original project designs.

Furthermore, while both Project-Based Learning and Augmented Reality have individually demonstrated positive impacts on student motivation, there remains a notable research gap regarding their systematic integration within elementary curricula. Most existing technology implementations treat AR as an isolated visual aid rather than a core component embedded within a structured project workflow. Synthesizing AR technology with the pedagogical phases of PjBL creates an innovative learning environment where technology directly serves active creation. Therefore, developing and evaluating an integrated AR-PjBL learning media is essential to establish a robust, interactive framework that effectively enhances elementary school students' creative thinking skills.

The Problem of The Study

Based on the background and existing research findings, the main problem addressed in this study lies in the limited development of elementary school students' creative thinking skills, which is closely related to the dominance of teacher-centered learning practices and the lack of innovative instructional approaches. Learning activities tend to provide minimal opportunities for students to actively explore ideas, engage in

problem-solving, and express creativity (Wulandari et al., [2021](#)).

In addition, although Project-Based Learning has been recognized as an effective model for fostering creative thinking, its implementation in elementary education is still not optimally supported by interactive and technology-based learning media. On the other hand, augmented reality has demonstrated significant potential in enhancing engagement and conceptual understanding; however, its use in classrooms is often fragmented and not systematically integrated into pedagogical frameworks (Simbolon & Koeswanti, [2020](#)).

This condition highlights a critical issue in which the potential synergy between Project-Based Learning and augmented reality has not been fully explored, particularly in supporting the development of students' creative thinking skills. Therefore, there is a need to design and develop an integrated learning media that combines both approaches into a cohesive and effective instructional strategy.

The root of the problem lies in the persistent reliance on passive learning paradigms, which treat elementary students as passive recipients of abstract knowledge rather than active problem solvers. In many elementary classrooms, instructional delivery continues to depend heavily on traditional textbooks and static visual aids. These traditional resources fail to provide dynamic visual or spatial representations, making it difficult for young learners to grasp complex, abstract concepts. As a result, students frequently experience cognitive barriers that restrict their ability to generate original ideas, think flexibly, and elaborate on creative solutions.

Furthermore, while active learning models like Project-Based Learning (PjBL) have been introduced to foster student engagement, their practical execution often lacks the necessary technological scaffolding. Elementary teachers frequently struggle to maintain high levels of student motivation and conceptual clarity during multi-step project tasks without interactive supporting media. Conversely, when emerging technologies such as Augmented Reality (AR) are introduced into classrooms, they are predominantly utilized as standalone visual demonstrations rather than being systematically aligned with pedagogical workflows. This fragmented usage prevents AR technology from reaching its full potential as an active scaffold for higher-order thinking.

Research's State of the Art

Recent research over the past five years has demonstrated that Project-Based Learning effectively enhances students' creative thinking skills across various educational contexts. PjBL provides opportunities for students to develop ideas collaboratively and engage in higher-order thinking processes (Umayana & Yustiana, [2024](#)). On the other hand,

augmented reality has been increasingly utilized in education due to its ability to visualize abstract concepts and create interactive learning environments.

Several studies have confirmed that AR-based learning media can improve students' motivation, engagement, and understanding of complex concepts. Furthermore, AR has been identified as a tool that supports creativity by enabling students to interact with digital content in meaningful ways (Yulinda et al., [2024](#)). Despite these advancements, most existing studies tend to focus on either the implementation of PjBL or the use of AR separately, rather than integrating both within a cohesive instructional framework.

Over the past decade, extensive literature has highlighted the pivotal role of Project-Based Learning (PjBL) in shifting classroom dynamics toward active, student-centered learning. Research consistently demonstrates that PjBL provides a structured framework where students engage in authentic, inquiry-driven tasks that foster higher-order thinking skills. Specifically, empirical studies show that when elementary students work collaboratively to solve real-world problems and construct tangible project artifacts, they exhibit significant improvements in cognitive flexibility, problem identification, and creative expression. However, scholars also note that PjBL implementation alone can sometimes be limited by students' conceptual bottlenecks when tackling abstract topics without sufficient cognitive scaffolding.

In parallel, the educational integration of immersive technologies, particularly Augmented Reality (AR), has gained remarkable momentum in recent educational research. Numerous studies have established that AR enhances learning experiences by overlaying 3D digital objects onto real-world physical spaces, thereby bridging the gap between abstract concepts and concrete visualization. In elementary education, AR application has been proven to significantly increase student learning motivation, spatial perception, and conceptual comprehension. By offering multi-sensory and interactive feedback, AR enables young learners to manipulate digital models, test visual hypotheses, and explore creative design possibilities that are impossible through conventional static media.

Despite these parallel advancements in active learning models and educational technologies, current state-of-the-art literature reveals a predominant focus on studying PjBL and AR independently. Most existing research either investigates PjBL as a purely pedagogical strategy without leveraging modern immersive tech, or treats AR technology as a standalone visual aid isolated from structured instructional syntaxes. Very few studies have systematically investigated

the holistic integration of AR directly into the specific stages of PjBL to nurture elementary students' creative thinking skills. This creates a timely opportunity to bridge this gap by establishing an integrated AR-PjBL framework that combines technological scaffolding with project-based inquiry.

Novelty, Research Gap, & Objective

The novelty of this study lies in the development of augmented reality-based learning media that is systematically integrated with the Project-Based Learning model. Unlike previous studies that treat AR as a supplementary tool or PjBL as a standalone instructional model, this study combines both elements into a comprehensive learning design.

Additionally, the developed media is specifically designed to support each stage of the PjBL process, including problem identification, project planning, implementation, and evaluation. This integrated approach is expected to provide a more meaningful, interactive, and immersive learning experience that fosters students' creative thinking skills more effectively (Listiani, [2020](#)).

Although numerous studies have explored the effectiveness of Project-Based Learning and augmented reality independently, there is still a lack of research that systematically integrates these two approaches into a unified learning design, particularly at the elementary school level (Anggraeny, [2020](#)). Existing studies on AR often emphasize visualization and engagement, while research on PjBL focuses primarily on instructional processes without leveraging advanced technology.

Moreover, limited studies have specifically examined the impact of integrating AR with PjBL on students' creative thinking skills (Ching & Hsu, [2024](#)). This indicates a gap in the literature regarding how technology-enhanced project-based learning environments can be designed to optimize creativity development among young learners.

In response to the identified problems, this study aims to develop an augmented reality-based learning media that is systematically integrated with the Project-Based Learning model for use in elementary education (Ramírez-Montoya et al., [2022](#)). The study seeks to produce a learning innovation that not only aligns with technological advancements but also supports the development of students' creative thinking skills.

Furthermore, this study aims to evaluate the feasibility of the developed learning media through expert validation and user assessment, ensuring that it meets educational standards and practical classroom needs. In addition, the study intends to examine the effectiveness of the integrated approach in improving students' creative thinking skills, as well as to explore students' responses toward the implementation of augmented reality in project-based learning activities.

Through these objectives, the study is expected to contribute to the development of

more interactive, meaningful, and creativity-oriented learning practices in elementary schools.

The fundamental novelty of this study lies in the systematic design and development of an Augmented Reality (AR) media that is directly embedded into every operational phase of the Project-Based Learning (PjBL) framework for elementary education. Unlike previous instructional media that utilize AR merely as a supplementary visual tool or treat PjBL as a purely conventional pedagogical framework, this research unifies both components into a cohesive, technology-enhanced instructional design. By seamlessly aligning interactive 3D digital elements with project workflows—such as problem identification, collaborative planning, hands-on prototyping, and final presentation—this media creates a dynamic learning space where digital immersion directly supports active project creation.

A critical research gap exists in the educational literature regarding how immersive technologies can be combined with active learning syntaxes specifically tailored to foster creative thinking in young learners. While prior studies have extensively documented the independent benefits of PjBL in encouraging collaboration and AR in enhancing visual motivation, there is a distinct lack of empirical evidence addressing their synergistic impact at the elementary school level. Existing AR interventions frequently focus on passive content consumption rather than constructive creation, whereas PjBL studies often struggle with conceptual bottlenecks when handling abstract concepts without visual scaffolding. This study bridges this empirical gap by demonstrating how an integrated AR-PjBL strategy optimizes students' creative thinking skills across all key indicators: fluency, flexibility, originality, and elaboration.

In response to these identified gaps and pedagogical needs, the primary objective of this study is to develop, validate, and evaluate an innovative AR-integrated PjBL learning media for elementary school instruction. Specifically, the study aims to assess the media's feasibility through rigorous expert validation covering content, instructional design, and user interface standards. Furthermore, it seeks to evaluate the practicality of the media based on real-world classroom implementation and user feedback from both teachers and fourth-grade students.

METHOD

Type and Design

This study employed a Research and Development (R&D) approach aimed at developing and evaluating an augmented reality (AR)-based learning media integrated with the Project-Based Learning (PjBL) model. The research design adopted the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation.

In the analysis stage, the researchers identified students' needs, curriculum requirements, and existing problems related to creative thinking skills. The design stage involved planning the structure of the AR media and aligning it with the stages of PjBL. During the development stage, the AR-based learning media was created and validated by experts. The implementation stage involved applying the developed media in a classroom setting. Finally, the evaluation stage was conducted to assess the feasibility and effectiveness of the media in improving students' creative thinking skills.

Data and Data Sources

The data in this study consisted of qualitative and quantitative data. Qualitative data were obtained from expert validation comments and suggestions, while quantitative data were derived from validation scores, teacher and student response questionnaires, and students' pretest and posttest results.

The data sources included instructional design experts, subject matter experts, and language experts who evaluated the developed module. The research subjects were fourth-grade elementary school students from two schools, serving as experimental and control groups during the effectiveness testing phase.

Data Collection Technique

Data were collected using several instruments. Expert validation sheets were used to assess the feasibility of the module in terms of instructional design, content accuracy, and language clarity. Teacher and student response questionnaires were administered to evaluate the practicality of the module after implementation.

To measure effectiveness, a conceptual understanding test was administered in the form of pretest and posttest. The test instruments were previously analyzed for validity, reliability, discrimination index, and difficulty level to ensure measurement accuracy.

Data Analysis

Data analysis in this study was conducted descriptively with the aim of describing the media development process, the feasibility level of the product, and the improvement of elementary school students' creative thinking skills after the use of Augmented Reality (AR) media integrated with Project-Based Learning (PjBL). The data analyzed consisted of qualitative and quantitative data. Qualitative data were obtained through interviews, observations, and expert judgment on the developed media. The qualitative data analysis was carried out through the stages of data reduction, data presentation, and conclusion drawing to identify the strengths, weaknesses, and necessary improvements of the product.

Meanwhile, quantitative data were obtained from expert validation questionnaires, student and teacher response questionnaires, and students' creative thinking skills tests conducted before (pre-test) and after (post-test) the learning process. The data from expert validation were analyzed by calculating the average score to determine the feasibility level of the media, which was then categorized into specific criteria. Student and teacher responses were analyzed using percentages to determine the practicality and attractiveness of the media in learning. Furthermore, the improvement in students' creative thinking skills was analyzed by comparing pre-test and post-test results and calculating the gain score (*N-gain*) to determine the effectiveness of the media. All data analysis results were then presented in descriptive narrative form, supported by tables and graphs, to provide a clear overview of the feasibility, practicality, and effectiveness of Augmented Reality media based on Project-Based Learning in improving elementary school students' creative thinking skills.

To evaluate the validity and feasibility of the developed media, the average score obtained from the expert validation sheets was converted into qualitative feasibility criteria using a 5-point Likert scale. The interval categories were defined as follows: Very Poor (1.00 – 1.80), Poor (1.81 – 2.60), Fair (2.61 – 3.40), Good (3.41 – 4.20), and Very Good (4.21 – 5.00). A minimum average score within the "Good" category was set as the benchmark for declaring the AR media feasible for classroom trials.

The practicality analysis of the AR media was evaluated using percentage calculations derived from student and teacher response questionnaires administered post-implementation. The formula used to calculate the response percentage was $P = \left(\frac{f}{N}\right) \times 100\%$, where *P* represents the practicality percentage, *f* is the total empirical score obtained, and *N* is the maximum possible score. The resulting percentages were mapped into four practicality criteria: Less Practical (< 60%), Practical Enough (60% – 74%), Practical (75% – 84%), and Very Practical (85% – 100%).

To measure the effectiveness of the media in improving students' creative thinking skills, the normalized gain (*N-gain*) formula proposed by Hake was utilized. The *N-gain* score was calculated as $g = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{max}} - S_{\text{pre}}}$, where *S*_{post} represents the average post-test score, *S*_{pre} denotes the average pre-test score, and *S*_{max} is the ideal maximum score. The resulting *N-gain* values were categorized into High ($g \geq 0.70$), Moderate ($0.30 \leq g < 0.70$), and Low ($g < 0.30$)

RESULTS

The results of this study describe the feasibility, practicality, and effectiveness of Augmented Reality (AR) media integrated with Project-Based Learning (PjBL) in improving elementary school students' creative thinking skills (Chardonnens, [2025](#)).

The feasibility of the developed AR media was determined through expert validation involving media experts, material experts, and learning experts. The results showed that the overall average validation score was 4.45 out of 5.00, which falls into the "very good" category. This indicates that the AR media is highly feasible for use in the learning process. Detailed results of expert validation are presented in Table 1

Table 1. Expert Validation Results

Aspect	Mean Score	Category
Media Design	4.50	Very Good
Content Accuracy	4.40	Very Good
Learning Design	4.45	Very Good
Overall Average	4.45	Very Good

Based on expert suggestions, several revisions were made, including improving visual clarity, simplifying navigation, and aligning the content more closely with learning objectives.

The practicality of the AR media was analyzed based on student and teacher responses after implementation. The results showed that the average percentage of student responses reached 88%, while teacher responses reached 91%, both categorized as "very practical." Students reported that the media was engaging, interactive, and easy to use, while teachers noted that it supported active learning and facilitated project-based activities. The detailed results are shown in Table 2.

Table 2. Practicality Test Results

Respondents	Percentage	Category
Students	88%	Very Practical
Teachers	91%	Very Practical

The effectiveness of the AR media in improving students' creative thinking skills was measured through pre-test and post-test scores. The results indicated a significant improvement in students' performance. The average pre-test score was 62.30, while the

post-test score increased to 84.75. The N-gain score was calculated at 0.60, which falls into the “moderate” category, indicating a meaningful improvement in creative thinking skills. The comparison of scores is presented in Table 3.

Table 3. Pre-test and Post-test Results

Test Type	Mean Score
Pre-test	62.30
Post-test	84.75
N-gain	0.60

Overall, these results indicate that the developed Augmented Reality media is feasible, practical, and effective in improving elementary school students' creative thinking skills. The integration of AR with Project-Based Learning provides meaningful and engaging learning experiences, encouraging students to actively participate and develop their creativity.

DISCUSSIONS

The findings of this study indicate that the developed Augmented Reality (AR) media integrated with Project-Based Learning (PjBL) is highly feasible for use in elementary school learning. The expert validation results, which fall into the “very good” category, suggest that the media meets key standards in terms of content accuracy, instructional design, and visual presentation (Merritt, 2021). This implies that combining AR technology with structured learning models can produce instructional media that is both pedagogically sound and technologically appropriate (Wulandari et al., 2021). The revisions made based on expert feedback further strengthened the quality of the product, ensuring its alignment with curriculum objectives and student characteristics.

In terms of practicality, the high percentage of positive responses from both students and teachers demonstrates that the AR media is easy to use and engaging in classroom settings. Students' enthusiasm reflects how interactive visualizations and immersive experiences can increase motivation and attention during learning activities (Wulandari et al., 2021). Teachers also found the media helpful in facilitating instruction, particularly in guiding students through project-based tasks (Sulistiyani, 2022). This supports the idea that innovative digital media can reduce instructional barriers and create a more dynamic and student-centered learning environment.

The effectiveness of the AR media is evident from the improvement in students' creative thinking skills, as shown by the increase in post-test scores and the moderate N-gain value. This indicates that the integration of AR with PjBL contributes meaningfully to

students' cognitive development, particularly in aspects of creativity such as fluency, flexibility, originality, and elaboration. The project-based approach allows students to explore ideas, solve problems, and produce tangible outputs, while AR enhances their understanding through visualization and interaction with abstract concepts.

Furthermore, the use of AR media in a PjBL framework encourages active learning and collaboration among students. During the learning process, students are not only passive recipients of information but also active participants who construct knowledge through exploration and project development. This aligns with constructivist learning theory, which emphasizes the importance of learner engagement and experience in knowledge construction. The combination of AR and PjBL creates opportunities for meaningful learning experiences that go beyond traditional instructional methods.

Another important finding is that AR technology helps bridge the gap between abstract concepts and students' real-world understanding. Elementary school students often face difficulties in grasping abstract or complex material, and AR provides concrete visual representations that make learning more accessible. This visual and interactive support enhances students' comprehension and stimulates their imagination, which in turn contributes to the development of creative thinking skills.

Despite the positive findings, this study also has several limitations. The implementation was conducted within a limited sample and timeframe, which may affect the generalizability of the results. Additionally, the study focused primarily on creative thinking skills, without exploring other potential learning outcomes such as critical thinking or problem-solving in depth (Simbolon & Koeswanti, 2020). Future research is recommended to involve larger and more diverse samples, extend the duration of implementation, and examine the impact of AR-based PjBL on various cognitive and affective domains.

In conclusion, the integration of Augmented Reality media with Project-Based Learning proves to be an effective approach to improving elementary school students' creative thinking skills. The media is not only feasible and practical but also capable of enhancing student engagement and learning outcomes. These findings suggest that educators should consider incorporating AR technology and project-based strategies into their teaching practices to create more innovative and meaningful learning experiences.

CONCLUSION

This study concludes that the development of Augmented Reality (AR) media integrated with Project-Based Learning (PjBL) is feasible, practical, and effective in improving elementary school students' creative thinking skills. The feasibility of the developed media is supported by expert validation results, which indicate that the product meets high standards in terms of content, design, and instructional quality. The revisions

made based on expert suggestions further enhanced the overall quality and suitability of the media for classroom implementation (Ilmi et al., 2023).

In terms of practicality, the positive responses from both students and teachers demonstrate that the AR-based learning media is easy to use, engaging, and supportive of the learning process. The integration of AR technology with a project-based approach creates an interactive learning environment that encourages student participation and facilitates meaningful learning experiences.

The effectiveness of the media is reflected in the significant improvement in students' creative thinking skills, as evidenced by the increase in post-test scores and the moderate N-gain results. This indicates that the use of AR media integrated with PjBL contributes positively to students' ability to generate ideas, think flexibly, and produce creative outcomes.

Overall, the integration of Augmented Reality with Project-Based Learning provides an innovative instructional approach that not only enhances student engagement but also supports the development of essential 21st-century skills, particularly creative thinking. Therefore, this study recommends the use of AR-based PjBL as an alternative learning strategy in elementary education to create more effective and meaningful learning experiences.

REFERENCES

- Anggraeny, et al. (2020). Analisis Teknologi Pembelajaran dalam Pendidikan Sekolah Dasar. *Fondatia*, 4(1), 150–157. <https://doi.org/10.36088/fondatia.v4i1.467>
- Chardonens, S. (2025). Adapting educational practices for Generation Z: integrating metacognitive strategies and artificial intelligence. *Frontiers in Education*, 10. <https://doi.org/10.3389/feduc.2025.1504726>
- Ching, Y. H., & Hsu, Y. C. (2024). Educational Robotics for Developing Computational Thinking in Young Learners: A Systematic Review. *TechTrends*, 68(3), 423–434. <https://doi.org/10.1007/s11528-023-00841-1>
- Doğan, Y., Batdı, V., Topkaya, Y., Özüpekçe, S., & Akşab, H. V. (2025). Effectiveness of Artificial Intelligence Practices in the Teaching of Social Sciences: A Multi-Complementary Research Approach on Pre-School Education. *Sustainability* (Switzerland), 17(7). <https://doi.org/10.3390/su17073159>
- Ilmi, L., Azizah, R., & Happy, N. (2023). Efektivitas Model Pembelajaran Problem-Based Learning (PBL) dan Guided Inquiry terhadap Kemampuan Berpikir Kritis Matematis Siswa. 1(4), 30–36. <https://doi.org/10.26877/imajiner.v1i4.3853>
- K. Perayani, & I.W. Rasna. (2022). Pembelajaran Keterampilan Menyimak Dengan Menggunakan Media Podcast Berbasis. Model Pembelajaran Project Based

-
- Learning (Pjbl)*. *Jurnal Pendidikan Dan Pembelajaran Bahasa Indonesia*, 11(1), 108–117. https://doi.org/10.23887/jurnal_bahasa.v11i1.741
- Listiani, T. (2020). Penggunaan Model PACE dalam Pembelajaran Geometri Topik Bangun Ruang. *Mosharafa: Jurnal Pendidikan Matematika*, 9(3), 407–418. <https://doi.org/10.31980/mosharafa.v9i3.711>
- Merritt, et al. (2021). Problem-based learning in K-8 mathematics and science education: A literature review. *Interdisciplinary Journal of Problem-Based Learning*, 11(2), 5–17. <https://doi.org/10.7771/1541-5015.1674>
- Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex Thinking in the Framework of Education 4.0 and Open Innovation—A Systematic Literature Review. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1). <https://doi.org/10.3390/joitmc8010004>
- Simbolon, R., & Koeswanti, H. D. (2020). Comparison of pbl (Project Based Learning) models with pbl (problem based learning) models to determine student learning outcomes and motivation. *International Journal of Elementary Education*, 4(4), 519–529. <https://doi.org/10.23887/ijee.v4i4.30087>
- Sulistiyani, N. (2022). Implementation of Problem-Based Learning Model (Pbl) Based on Reflective Pedagogy Approach on Advanced Statistics Learning. *IJJET (International Journal of Indonesian Education and Teaching)*, 2(1), 11–19. <https://doi.org/10.24071/ijiet.v2i1.952>
- Umay, R., & Yustiana, S. (2024). Pengaruh Model Pembelajaran Project-Based Learning Berbantuan Podcast Bermuatan Edukasi Terhadap Kemampuan Mendengarkan Dan Berbicara Siswa Kelas 6 Sdn 1 Tempuran. *PGSD UNIGA*. <https://doi.org/10.52434/jpgsd.v4i1.42181>
- Wulandari, A. S., Suardana, I. N., & Devi, N. L. P. L. (2021). Pengaruh Model Pembelajaran Berbasis Proyek Terhadap Kreativitas Siswa Smp Pada Pembelajaran Ipa. *Jurnal Pendidikan Dan Pembelajaran Sains Indonesia (JPPSI)*, 2(1), 47. <https://doi.org/10.23887/jppsi.v2i1.17222>
- Yulinda, D., Yundayani, A., & Juhana, J. (2024). Students' Perspective on the Implementation of Gagne's Nine Instructional Events in Collaborative Project-Based English Language Teaching. *Lectura : Jurnal Pendidikan*, 15(1), 64–82. <https://doi.org/10.31849/lectura.v15i1.17249>
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