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THE EFFECTIVENESS OF PROBLEM-BASED LEARNING ON THE DEVELOPMENT OF SPATIAL SKILLS AMONG JUNIOR HIGH SCHOOL STUDENTS: A SYSTEMATIC LITERATURE REVIEW

Idzni Arenta Dinia Putty[1], Fatqurhohman[2], Nurul Imamah Ah[3]
Universitas Muhammadiyah Jember, Jawa Timur, Indonesia
idzniarent@gmail.com

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Abstrack

Many reports show that Junior High School students still face difficulties in spatial abilities, especially in geometry. Students often struggle with visualizing objects, interpreting 3D representations, and performing mental rotations. Learning that is still teacher-centered also limits students' opportunities to explore and develop spatial reasoning. This study aims to analyze the effectiveness of the Problem Based Learning (PBL) model in developing students' spatial abilities through a systematic literature review (SLR) approach. The review was conducted using the PRISMA guidelines to ensure a transparent and comprehensive selection process. The study examined eight selected articles identified by Google Scholar, Garuda, and Academia. The analysis reveals that PBL effectively enhances middle school students' spatial abilities in mathematics, particularly in visualization, mental rotation, and spatial reasoning. The model also strengthens critical, creative, and reflective thinking as essential 21st-century competencies. Furthermore, technology-assisted PBL such as SketchUp and differentiated facilitation based on cognitive styles further optimize learning outcomes. However, challenges remain in teacher readiness and access to digital media. The findings confirm that PBL is not only an effective instructional method but also a transformative pedagogical approach to cultivate spatial intelligence and problem-solving skills in mathematics education.

Keywords: Problem Based Learning, Spatial Ability, Mathematics Education, 21st-Century Skills, Systematic Literature Review

INTRODUCTION

21st-century education demands that students have complex competencies along with technological advances, globalization, and the development of science, so that critical, creative, collaborative, and communicative thinking skills are needed to face the challenges of a dynamic life. (Moshinski et al., 2021). In addition to mastering theory, students must also have high-level thinking skills and an adaptive attitude in solving real problems, even though their application still faces obstacles. (Mutohhari et al., 2021) One of the important competencies in this case is spatial ability, namely understanding the relationship between objects and space and analyzing spatial representations that play a role in various fields such as mathematics, science, geography, design, and technology. (Ayuwandari, 2019); (Rangkuti & Juniati, 2022). The scientific approach has been proven to improve students' analytical and spatial abilities. (Rahayu et al., 2021), while 21st-century learning emphasizes the integration of objectives, authentic assessments, and meaningful experiences so that students are able to relate abstract concepts to real contexts. (Fatqurhohman et al., 2025) In this context, learning mathematics plays a role in training critical, systematic, and analytical thinking patterns through pattern recognition and generalization of concepts as a basis for

logical thinking. (Aini et al., 2020) Therefore, the development of critical spatial thinking, including in mathematics learning, is important to support students' life skills in the global era. (Safira, 2023).

In addition to its importance in mathematics and science learning, spatial ability has strong theoretical foundations in cognitive psychology. Fundamentally, spatial ability is defined as an individual's capacity to understand, recall, manipulate, and transform visual spatial information related to objects and their positional relationships. According to Thurstone's classic theory of primary mental abilities, spatial ability represents a core cognitive skill that enables individuals to interpret spatial patterns and mentally manipulate shapes. Similarly, Linn and Petersen categorize spatial ability into several major components spatial visualization, mental rotation, and spatial perception each of which plays a crucial role in representing, transforming, and reasoning about two- and three-dimensional objects.

Within the context of mathematics education, spatial ability serves as the cognitive foundation for understanding geometry, interpreting three-dimensional forms, analyzing transformations, and recognizing structural relationships among shapes. These skills allow students to mentally construct spatial relations, interpret orientations, and solve visual–spatial problems more effectively. Therefore, developing spatial ability is a fundamental aspect of higher-order mathematical thinking and contributes directly to strengthening students' mathematical literacy and 21st-century problem-solving competencies.

Although spatial abilities have an important role in supporting various areas of learning, their development in students often faces a number of problems and challenges. Nurwijaya (2022) emphasized that the limitations of learning media and the lack of variety of teacher strategies in facilitating spatial visualization can be obstacles in the learning process. In addition, Mardhatillah (2022) research show that in online learning, students tend to have difficulty optimally developing spatial thinking skills due to limited direct interaction with real objects and spaces. Other obstacles also arise from low motivation and students' tendency to focus more on memorization than on in-depth exploration of spatial concepts. (Fathia, 2022) This shows that spatial skills require a more structured, innovative, and contextual learning approach to develop in line with the demands of the 21st century.

The application of the right learning model is key to developing students' spatial abilities, and Problem Based Learning (PBL) is a learning approach that guides students to actively solve problems that are relevant to real life (Azzahra et al., 2023). This learning model contributes to increasing student motivation by encouraging them to collaborate in groups to solve challenges related to real-life situations (Kusuma, 2020). Through this collaboration, students can develop social skills and critical thinking skills in dealing with various issues relevant to everyday life.

Through guided inquiry, PBL creates ideal conditions for the development of spatial concepts (Khoiriah & Suryani, 2023), while supporting job readiness through mastery of 21st-century skills such as spatial abilities (Vanzal & Dwiningsih, 2023) Research shows the effectiveness of PBL in improving learning outcomes, creativity, and problem-solving skills in various fields, including physics and biology. (Silviariza et al., 2023) Its integration into online learning also increases interactivity, solution exploration, and student learning outcomes. (Rabattu et al., 2023), even strengthening mathematical disposition and problem-solving abilities (Yang et al., 2023). Research shows the effectiveness of PBL in improving learning outcomes, creativity, and problem-solving skills in various fields, including physics and biology (Silviariza et al., 2023). The issues studied in the learning process should also take into account the cultural background of the students because cultural aspects play an important role in deepening their understanding of the material. The cultural context helps learners connect the concepts they learn with their experiences and values, making learning more meaningful and contextual (Ah, N. I., & Purnomo, E. (2025).

Various studies indicate that PBL has a positive impact on improving students' critical thinking skills, problem solving, and spatial

abilities. Antunes et al. (2023) found that PBL improves conceptual understanding and spatial skills through the application of theory in practical situations, while Mutiah et al. (2023) found that students who learn with PBL have a better understanding of mathematical and scientific concepts that require spatial abilities. However, although the effectiveness of PBL has been widely demonstrated, there is still a research gap regarding the extent of its specific impact on spatial abilities and the factors that influence its success. (Marlina & Azis, 2023). Most studies still focus on general learning outcomes without examining in depth the contribution of PBL to the development of interdisciplinary spatial skills. (Azzahra et al., 2023). Thus, a systematic study is needed that comprehensively examines the relationship between the implementation of PBL and the development of students' spatial abilities.

The novelty of this research lies in its focus, which specifically examines the influence of PBL on the development of students' spatial abilities through a systematic literature review approach. Previous studies generally discuss cognitive aspects or overall learning outcomes, but this study examines in depth the contribution of PBL to spatial skills, an important and rarely studied competency of the 21st century. This study aims to provide a comprehensive overview of how the implementation of PBL supports the development of junior high school students' spatial abilities in mathematics by considering contextual factors such as teacher strategies, student characteristics, media, and the learning environment. Through this review, it is hoped that general patterns and significant differences in the implementation of PBL will be obtained as a basis for developing more adaptive and relevant learning strategies in the global era.

Based on the background, research gaps, and objectives that have been outlined, this research is focused on answering the main question: "How effective is PBL in developing students' spatial abilities in junior high school in mathematics learning?"

METHOD

This study used a Systematic Literature Review (SLR) design, which aims to identify, evaluate, and synthesize relevant research findings on the effectiveness of problem-based learning on students' spatial ability development in the context of 21st-century education. The SLR method was chosen because it provides a comprehensive and transparent approach in summarizing published scientific evidence, thus providing a comprehensive picture of the contribution of PBL to spatial skills. To ensure systematic and transparent research implementation, this study is conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. These guidelines provide a clear structure and flow in the process of identifying, selecting, and evaluating relevant literature.

The research procedure was carried out through four main stages according to the PRISMA flow, namely, identification, screening, eligibility, and inclusion.

1. *Identification*
   At this stage, a systematic literature search was conducted through academic databases such as Google Scholar, Garuda, and Academia using the keywords "problem-based learning," "spatial ability," and "21st-century skills." The initial search results identified 640 articles, consisting of 220 articles from Google Scholar, 4 articles from Garuda, and 416 articles from Academia. The articles covered were published between 2021 and 2025 and written in both Indonesian and English. All articles relevant to the research topic were collected for further analysis.
2. *Screening*
   At this stage, article titles and abstracts were reviewed to ensure their relevance to the research topic. Articles that did not discuss the application of PBL, did not relate to spatial skills, or did not meet the initial criteria were excluded. The screening results yielded 50 articles deemed relevant, while 590 articles were excluded for not meeting the initial criteria.
3. *Eligibility*
   This stage is carried out by reading the full text of articles that pass screening to assess compliance with the eligibility criteria, namely:
   a. research that explicitly examines the application of PBL,

b. research that discusses the development of spatial abilities of junior high school students,
c. articles that present empirical data or comprehensive reviews regarding the effectiveness of PBL in mathematics learning in the context of 21st century skills.

This process eliminated duplicates and excluded articles that did not align with the research focus, leaving 43 articles. Furthermore, after a full eligibility assessment, only eight articles met all criteria, while 35 others were excluded for not meeting the requirements.

4. *Inclusion*

Eight articles that met all eligibility criteria were then included in the final review. These articles were analyzed in depth to synthesize scientific evidence regarding the effectiveness of PBL implementation in improving junior high school students' spatial abilities. This included reviewing the role of PBL in developing spatial abilities, the effectiveness of the learning strategies used, and the challenges and opportunities for its implementation in 21st-century mathematics learning.

Data analysis was conducted using a qualitative approach through thematic synthesis. Data extracted from the articles included research methods, PBL implementation strategies, developed spatial ability indicators, and reported research results. The data were then synthesized to identify general patterns, contextual differences, and factors influencing the success of PBL implementation. This analysis is expected to provide a comprehensive understanding of the effectiveness of PBL in developing students' spatial abilities while also providing practical recommendations for developing 21st-century learning strategies.

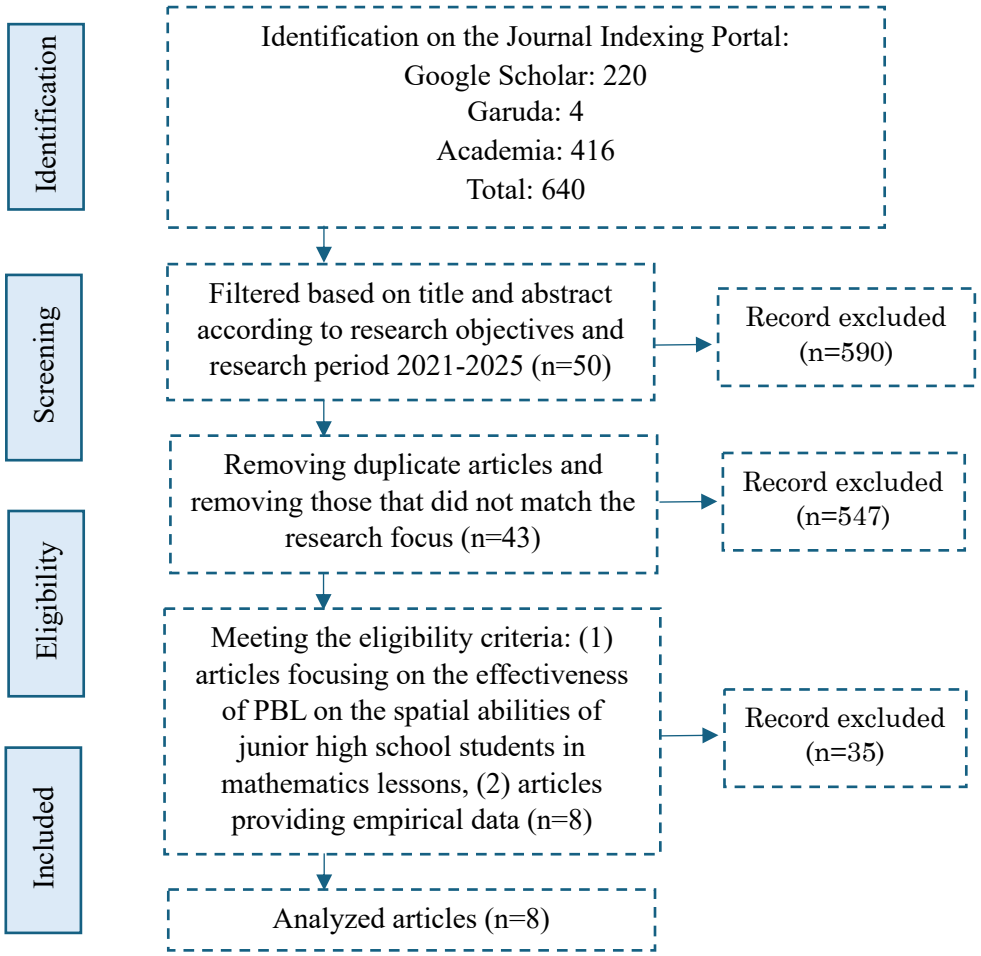


Figure 1. Stages of Systematic Literature Review

The articles included in this review were limited to the publication range 2021–2025. This range was chosen to ensure that the analysis reflects the most recent developments in problem-based learning (PBL), the integration of digital technology in mathematics education, and contemporary research on spatial ability. Considering rapid changes in 21st-century learning demands and technological advances, studies published before 2021 were not included because they may not fully represent current pedagogical trends, digital learning tools, or updated curriculum frameworks. Thus, the selected year range strengthens the relevance, recency, and validity of the synthesized findings.

RESEARCH RESULTS AND DISCUSSION

This SLR study examines the effectiveness of PBL in developing students' spatial abilities in junior high school mathematics. The following table summarizes eight related journals:

Table 1. Systematic Literature Review of 8 Journals

No	Title	Author & Year	Method	Results	Journal Index
1.	The Effectiveness of the Problem-Based Learning Model on Students' Mathematical Spatial Abilities	(Pitriyani et al., 2024)	Quantitative research with quasi-experimental method and pre-experimental research design	Based on the outcomes of the t-test, z-test, and gain test, it can be concluded that the use of a problem-based learning approach is effective in enhancing students' mathematical spatial skills.	Sinta 3
2.	Analyzing Cognitive Styles and Spatial Abilities in Geometry Transformations through the Problem-Based Learning Approach	(Syahbudin et al., 2024)	Descriptive qualitative approach	The results of the study showed a significant difference in spatial abilities between FI and FD students.	Sinta 2
3.	Implementation of Sketchup-Assisted PBL Model to Improve Spatial Ability of Grade VII Students	(Salamah et al., 2025)	Quantitative approach through experimental design	The research results showed an increase in students' spatial abilities across all indicators after implementing the SketchUp-assisted PBL model. Students demonstrated active engagement in learning and were able to construct and manipulate spatial	Sinta 3

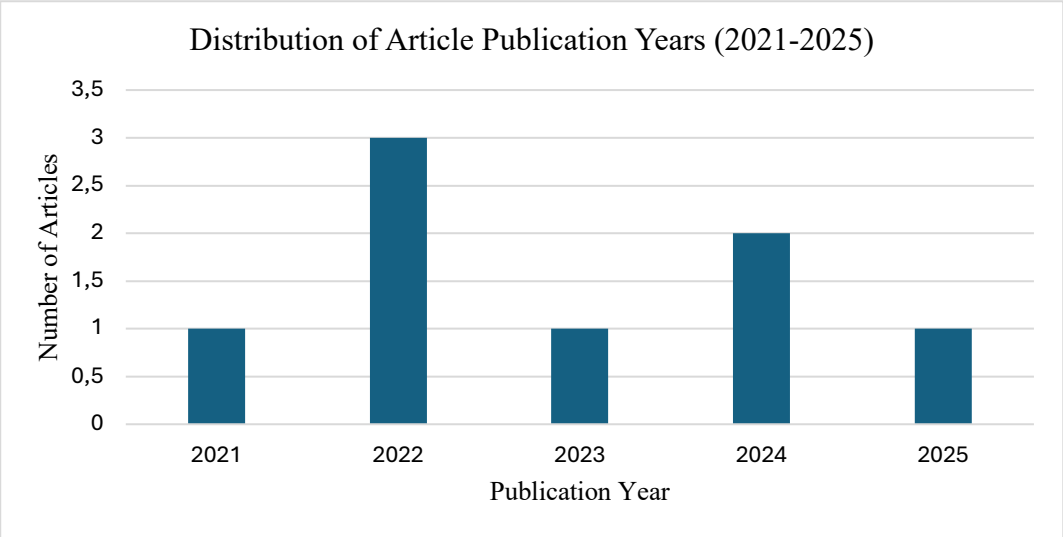
				objects independently using SketchUp.	
4.	The effect of the problem based learning and double loop problem solving learning models on problem solving ability in terms of creative thinking on environmental pollution material	(Permata et al., 2022)	Quasi-experiment	The research results are as follows: The PBL and DLPS instructional approaches did not have a meaningful impact on enhancing students' problem-solving abilities. A difference in problem-solving skills was observed between students with high creative thinking abilities and those with low creative thinking abilities.	Sinta 2
5.	Examining middle school teachers' implementation of a technology-enriched problem-based learning program: Motivational factors, challenges, and strategies	(Liu et al., 2021)	Qualitative research	The findings indicated that teachers' motivation stemmed not only from the alignment of PBL with their teaching beliefs, but also from the encouraging learning results demonstrated by students.	Scopus Q1
6.	The Effect of Problem-Based Learning on Middle School Students' Environmental Literacy and Problem-Solving Skills	(Gök & Boncukçu, 2023)	Experimental research	The findings revealed that PBL proved to be more effective in fostering environmental attitudes compared to traditional curriculum-based teaching. However, this method did not have the same effect on environmental behavior. Moreover, PBL led to a notable	Sinta 2

				increase in problem-solving abilities among students' in the experimental group, whereas the scores of those in the control group showed no improvement.	
7.	Enhancing Upper Secondary Learners' Problem-solving Abilities using Problem-based Learning in Mathematics	(Uworwabayeho, 2022)	Quasi-experimental research	The findings indicate that PBL has the capacity to enhance students' problem-solving skills. Based on the results of students' problem-solving work,	Scopus Q2
8.	Analysis of Problem-Solving Ability of Grade VII Students of SMP Negeri 4 Cibinong on Algebraic Forms Material with Problem Based Learning	(Soniawati, 2022)	Descriptive research	The results show that students at SMP Negeri 4 Cibinong have low problem-solving abilities. Various types of errors were identified in solving algebraic problems. About 49% of mistakes occurred in understanding the problem, 23% in planning a solution, 0% in carrying out the plan, and 9% in reviewing or checking the final answer.	Sinta 3

The Problem-Based Learning (PBL) model is considered a learning approach relevant to 21st-century demands because it emphasizes the development of critical, creative, collaborative, and problem-solving thinking skills through real-world context-based activities (Liu et al., 2021; Gök & Boncukçu, 2023). In junior high school mathematics learning, PBL provides students with the opportunity to construct an understanding of geometric concepts independently and reflectively. This approach requires students to integrate spatial thinking skills, including visualization, mental rotation, and spatial representation, as the basis for solving complex mathematical problems. The teacher is a facilitator who encourages students to learn on their own by having them work on real-world problems. This is in line with the 21st-century learning model, which sees students as active learners and creators of knowledge.

The effectiveness of PBL in developing mathematical spatial abilities has been proven through various empirical studies. Pitriyani,

Sundayana, and Maryati (2024) found that the application of PBL significantly improved junior high school students' spatial abilities in understanding shapes, dimensions, and spatial relationships in geometry. These results were supported by Salamah, Nurhayati, and Rustina (2025), who showed that the use of PBL assisted by SketchUp accelerated mastery of three-dimensional visualization and object rotation. Syahbudin, Priatna, and Yulianti (2024) added that the effectiveness of PBL is also influenced by students' cognitive styles: field-independent types excel in analytical visualization, while field-dependent types benefit more from collaborative work. Meanwhile, Permata, Sunarno, and Harlita (2022) and Soniawati (2022) proved that PBL improves creative thinking and mathematical problem-solving skills, which form the basis for strengthening spatial abilities. Uworwabayeho, Dorimana, and Nizeyimana (2022) also emphasized that PBL fosters metacognitive and reflective abilities through problem-based investigations, strengthening the relationship between spatial reasoning and contextual problem solving.



Conceptually and practically, the success of PBL in developing spatial abilities occurs because this model requires students to visualize, represent, and manipulate geometric objects mentally and concretely through collaboration and discussion. (Azzahra et al., 2023) However, Liu et al. (2021) and Gök and Boncukçu (2023) pointed out that there are still problems with teacher readiness and the limits of digital learning media. They stressed the need for professional training to make PBL work better in technology-based classrooms. To ensure equitable learning outcomes, educators should integrate visual media such as SketchUp (Salamah et al., 2025) and implement cognitive style-based differentiated PBL (Syahbudin et al., 2024). Thus, PBL has proven effective not only in improving junior high school students' spatial abilities but also in shaping the profile of 21st-century learners capable of reflective, creative, and collaborative thinking when facing mathematical and real-world problems.

CONCLUSION

Spatial ability is fundamentally recognized in cognitive psychology as a core component of human intelligence. Theories by Thurstone and later Linn & Petersen conceptualize spatial ability as a multidimensional construct consisting of spatial visualization, mental rotation, and spatial perception, all of which form the cognitive basis for understanding geometric structures and solving visual spatial problems.

In mathematics education particularly geometry these components are essential because students must mentally manipulate shapes, interpret three-dimensional representations, and construct spatial relations to achieve accurate conceptual understanding. Thus, any instructional model claiming effectiveness must demonstrate improvements across these core dimensions of spatial cognition.

Synthesizing the findings of the eight reviewed studies clearly answers the research question: PBL is consistently effective in developing junior high school students' spatial abilities, because it directly activates the cognitive processes theorized as the foundation of spatial reasoning. Evidence across studies demonstrates that:

(1) PBL strengthens spatial visualization, as students are required to interpret real-world spatial problems and construct mental models of geometric objects (Pitriyani et al., 2024; Salamah et al., 2025).

(2) PBL improves mental rotation, particularly when supported by technology such as SketchUp, which provides manipulable 3D models aligning with the mental rotation mechanism described in spatial cognition theory.

(3) PBL enhances spatial reasoning, as students must justify spatial relationships, compare geometric structures, and use representations flexibly during group inquiry (Syahbudin et al., 2024).

(4) PBL benefits diverse cognitive styles, showing that both field-independent and field-dependent learners experience measurable gains when spatial tasks are embedded in collaborative and problem-centered contexts.

(5) PBL's contextual problem-solving structure aligns with theoretical models of spatial learning, which state that spatial ability develops most effectively through active manipulation, visualization, and reflection.

Together, these findings provide convergent evidence that PBL does not merely support general cognitive growth, but specifically activates and enhances the core components of spatial ability theory, confirming its targeted effectiveness for junior high school mathematics.

REFERENCES

Ah, N. I., & Purnomo, E. (2025). IMPLEMENTASI PROBLEM BASED LEARNING MELALUI CULTURALLY RESPONSIVE TEACHING UNTUK MENINGKATKAN HASIL BELAJAR PESERTA DIDIK. SIGMA, 11(1), 74-82.

Aini, N., Imamah, N., & Ningtyas, Y. (2020). Kemampuan Generalisasi Matematis Siswa Smp Kelas Viii Pada Materi Pola Bilangan. *Universitas Muhammadiyah Jember*, *5*(1), 1–7.

Antunes, R., Aguiar, M. L., & Gaspar, P. D. (2023). A Dynamic STEM-Driven Approach through Mobile Robotics to Enhance Critical Thinking and Interdisciplinary Skills for Empowering Industry 4.0 Competencies. *Technologies*, *11*(6). https://doi.org/10.3390/technologies11060170

Ayuwandari, G. (2019). Suparman,"Design of PBL Mathematics Student Worksheets To Improve Student Learning Creativity For Junior High School." *Int. J. Sci. Technol. Res*, *8*(12), 3958–3964.

Azzahra, R., Muryani, C., & Tjahjono, G. A. (2023). DEVELOPMENT OF GIS-BASED LEARNING MULTIMEDIA TO IMPROVE SPATIAL THINKING ABILITY OF SOCIAL STUDENTS IN HIGH SCHOOL. *GeoEco*, *9*(2). https://doi.org/10.20961/ge.v9i2.74371

Fathia, N. (2022). Pengembangan Perangkat Pembelajaran PBL pada Google Classroom untuk Meningkatkan Kemampuan Spasial Matematika Kelas

VIII. *Jurnal Edukasi Matematika Dan Sains)*, *10*(1).

Fatqurhohman, F., Murniasih, T. R., Anwar, R. B., & Halim, F. A. (2025). The Role of UbD in Developing Students' Mathematical Problem-Solving Skills: A Literature Review. *Review of Education, Science, and Technology*, *1*(1), 29–42.

Gök, G., & Boncukçu, G. (2023). The Effect of Problem-Based Learning on Middle School Students' Environmental Literacy and Problem-Solving Skills. *Journal of Science Learning*, *6*(4), 414–423.

Khoiriah, U., & Suryani, I. (2023). Pengembangan LKPD Berbasis Problem Based Learning Pada Materi Bangun Ruang Kelas V SD. *Journal on Education*, *6*(1).

Liu, M., Shi, Y., Pan, Z., Li, C., Pan, X., & Lopez, F. (2021). Examining middle school teachers' implementation of a technology-enriched problem-based learning program: Motivational factors, challenges, and strategies. *Journal of Research on Technology in Education*, *53*(3), 279–295.

Mardhatillah, P. S., Fauzi, K. A., & Saragih, S. (2022). Pengembangan Media Pembelajaran Berbasis Adobe Flash Menggunakan Model Thinking Aloud Pair Problem Solving untuk Meningkatkan Kemampuan Spasial dan Resiliensi Matematis. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *6*(1).

Marlina, E., & Azis, F. (2023). The Ethnomathematical Concept of Sundanese Local Wisdom through Building Space for the Earth Alit Kabuyutan West Java Site as the Development of Mathematics Learning Media. *International Journal of Quantitative Research and Modeling*, *4*(2). https://doi.org/10.46336/ijqrm.v4i2.449

Moshinski, V., Pozniakovska, N., Mikluha, O., & Voitko, M. (2021). Modern education technologies: 21st century trends and challenges. *SHS Web of Conferences*, *104*, 3009.

Mutiah, S., Anwar, M., & Yani, S. (2023). GEOMA (GEOMETRI MATEMATIKA) APPLICATION AS GEOGEBRA-BASED LEARNING MEDIA TO TRAIN SPATIAL ABILITY. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(3). https://doi.org/10.24127/ajpm.v12i3.7540

Mutohhari, F., Sutiman, S., Nurtanto, M., Kholifah, N., & Samsudin, A. (2021). Difficulties in Implementing 21st Century Skills Competence in Vocational Education Learning. *International Journal of Evaluation and Research in Education*, *10*(4), 1229–1236.

Nurwijaya, S. (2022). Pengaruh Model Pembelajaran Problem Based Learning Berbantuan Augmented Reality Terhadap Kemampuan Spasial Siswa. *EQUALS: Jurnal Ilmiah Pendidikan Matematika*, *5*(2). https://doi.org/10.46918/equals.v5i2.1563

Permata, S. A. I., Sunarno, W., & Harlita, H. (2022). The effect of the problem based learning and double loop problem solving learning models on problem solving ability in term of creative thinking on environmental pollution material. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2647–2653.

Pitriyani, P., Sundayana, R., & Maryati, I. (2024). Efektivitas Model Problem-Based Learning terhadap Kemampuan Spasial Matematis Siswa. *Plusminus: Jurnal Pendidikan Matematika*, *4*(2), 347–356.

Rabattu, P. Y., Debarnot, U., & Hoyek, N. (2023). Exploring the impact of interactive movement-based anatomy learning in real classroom setting among kinesiology students. *Anatomical Sciences Education*, *16*(1). https://doi.org/10.1002/ase.2172

Rahayu, P. S., Handoyo, B., & Purwito, H. (2021). Penerapan pendekatan saintifik

dilengkapi LKS pada mata pelajaran Geografi untuk meningkatkan kemampuan berpikir analitis siswa kelas XI IPS 2 SMAN 8 Malang. *Jurnal Integrasi Dan Harmoni Inovatif Ilmu-Ilmu Sosial*, *1*(3), 336–349.

Rangkuti, R. K., & Juniati, D. (2022). Profile of MTs Students' Spatial Reasoning in Solving Contextual Problems Based on Mathematical Ability. *International Journal of Humanities Education and Social Sciences (Ijhess)*, *1*(6).

Safira, E. D. (2023). *Pengaruh Model Pembelajaran Project Based Learning Disertai Infografis Terhadap Critical Spatial Thinking Peserta Didik Kelas X SMA Negeri 1 Sukoharjo Tahun Ajaran 2022/2023*.

Salamah, S., Nurhayati, E., & Rustina, R. (2025). IMPLEMENTASI MODEL PBL BERBANTUAN SKETCHUP UNTUK MENINGKATKAN KEMAMPUAN SPASIAL PESERTA DIDIK KELAS VII. *JP2M (Jurnal Pendidikan Dan Pembelajaran Matematika)*, *11*(2), 1507–1515.

Silviariza, W. Y., Sumarmi, Utaya, S., Bachri, S., & Handoyo, B. (2023). Development of Evaluation Instruments to Measure the Quality of Spatial Problem Based Learning (SPBL): CIPP Framework. In *International Journal of Instruction* (Vol. 16, Issue 2). https://doi.org/10.29333/iji.2023.16223a

Soniawati, S. (2022). Analisis Kemampuan Pemecahan Masalah Siswa Kelas VII SMP Negeri 4 Cibinong Materi Bentuk Aljabar Dengan Problem Based Learning. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *5*(5), 1341–1350.

Syahbudin, F., Priatna, N., & Yulianti, K. (2024). Analyzing Cognitive Styles and Spatial Abilities in Geometry Transformations through the Problem-Based Learning Approach. *Jurnal Pendidikan Progresif*, *14*(3), 2130–2144.

Uworwabayeho, A. (2022). Enhancing upper secondary learners' problem-solving abilities using problem-based learning in mathematics. *International Journal of Learning, Teaching and Educational Research*, *21*(8), 235–252.

Vanzal, T., & Dwiningsih, K. (2023). Effectiveness of Android-Based Mobile Learning (M-Learning) on Molecular Shape Sub-Materials to Improve Students' Visual-Spatial Intelligence. *Jurnal Penelitian Pendidikan IPA*, *9*(9). https://doi.org/10.29303/jppipa.v9i9.4738

Yang, Y., Conde Santiago, S., Lasc, D., Hershkovich, A., & Grove, L. (2023). Informal STEM learning: Examples from everyday spatial behaviors. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1117771