

DAFTAR PUSTAKA

- Abuhassna, H., Al-Rahmi, W. M., Yahya, N., & Zakaria, M. A. (2024). Development of learning environments using instructional design models: A systematic review. *Education and Information Technologies*, 29(2), 1453–1475.
- Acevedo, A., et al. (2024). *Embodied immersive virtual reality to enhance the conceptual understanding of charged particles*. Computers & Education: X Reality.
- Acevedo, P., Choi, M., Magana, A. J., Benes, B., & Mousas, C. (2024). *The effects of immersion and dimensionality in virtual reality science simulations: The case of charged particles*. IEEE International Symposium on Mixed and Augmented Reality (ISMAR)
- Acosta, R. D. S., Cooper, E. M. H., & Medina, A. H. (2025). Electroweb: An innovative approach to teaching electromagnetism through web-based adaptive learning. *INTED Proceedings*.
- Adamczyk, P. D., & Eadkhong, T. (2025). Integrating problem-based learning into physics laboratory learning. *Eurasia Journal of Mathematics, Science and Technology Education*.
- Afrianita, L., Maison, M., & Kurniawan, D. A. (2022). Hasil observasi mengenai miskonsepsi listrik statis pada siswa SMAN 9 Kota Jambi. *Pena Kreatif: Jurnal Pendidikan*, 11(2).
- Al Hasanah, H., Iswanto, B. H., & Sugihartono, I. (2025). AI-CBL: A technology-enhanced learning model combining chatbot and case-based pedagogy to improve critical thinking in physics education. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 11(1), 109–122.
- Al-Hassan, M., et al. (2022). Simulations to teach science subjects: Connections among students' engagement, self-confidence, satisfaction, and learning styles. *Education and Information Technologies*,
- Ananda, F., Nurjannah, N., Werdhiana, I. K., Syamsuriwal, S., & Laratu, W. N. (2025). Analisis Pemahaman Mahasiswa Calon Guru Fisika Tentang Konsep Elektrostatika Berdasarkan Four Tier Multiple Choice (4TMC) Test. *JPFT (Jurnal Pendidikan Fisika Tadulako Online)*, 13(2), 171-181.
- Andi Ferawati Jafar (2021), THE IMPLEMENTATION OF THE CONVENTIONAL LEARNING METHOD TO PHYSICS LEARNING OUTCOMES OF

STUDENTS. Al asma: Journal of Islamic Education, Vol. 3, No. 2. ISSN 2715-2812

- Aquines Gutiérrez, A., et al. (2022). *Assisted discovery based learning of the electric force with scaffolding for novice students*. Journal of Physics Education Research.
- Aripin, W. A., Sahidu, H., & Makhrus, M. (2021). Efektivitas Perangkat Pembelajaran Fisika Berbasis Model Problem-Based Learning untuk Meningkatkan Kemampuan Pemecahan Masalah dan Kemampuan Berpikir Kritis Peserta Didik. *Jurnal Penelitian dan Pembelajaran Fisika Indonesia*, 3(1). 19–23.
- Auliya, M., & Fajrin, H. N. (2022). The effect of the amount of charge on the force and direction using PhET simulation. *Journal of Physics*.
- Ayu, H. D., Chusniyah, D. A., Kurniawati, M. P., Purwanti, P. F., Lukitawanti, S. D., & Putri, A. N. (2024). Problem-based learning (PBL) as an effective solution to enhance understanding of physics concepts: A systematic literature review. *Journal of Environment and Sustainability Education*, 2(2), 86–105.
- Ayu, H. D., et al. (2024). Problem-based learning (PBL) as an effective solution to enhance understanding of physics concepts: A systematic literature review. *Journal of Environment and Sustainability Education*, 2(2).
- Banda, H. J., & Nzabahimana, J. (2021). *Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature*. Physical Review Physics Education Research, 17(2), 023108.
- Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, 17(2), 023108.
- Becker, E., Wünsche, J., Veith, J. M., Schrader, P., & Bitzenbauer, P. (2025). From cognitive relief to affective engagement: An empirical comparison of AI chatbots and instructional scaffolding in physics education. *Uwambajimana, S., Minani, E., Mollel, A. D., & Nyirahabimana, P. (2023). The impact of using PhET simulation on conceptual understanding of electrostatics within selected secondary schools of Muhanga District, Rwanda. Journal of Mathematics and Science Teacher*, 3(2),
- Ben-Zion, M., et al. (2025). *Leveraging generative artificial intelligence for simulation-based physics experiments*. Computers & Education.

- Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education. *Educational Technology Research and Development*.
- Branch, R. M. (2020). *Instructional Design: The ADDIE Approach*. Springer.
- Campos, E., Troskot, P., Aschauer, W., & Hopf, M. (2025). Assessment of students' understanding of electric and magnetic fields in high school. *Physics Education*.
- Candraditya, R., Ningtyas, C. P., & Aziz, M. R. A. (2024). Understanding cyclotron motion: A visual approach to electron dynamics in electric and magnetic fields. *Journal of Science Education Research*.
- Çelik, B. (2022). The effects of computer simulations on students' science process skills: Literature review. *Canadian Journal of Educational and Social Studies*.
- Chairini, N. A. (2025). Pengaruh PBL terhadap pemahaman konsep siswa. *Repository Raden Intan*.
- Chandramidi, M. (2022). Pengembangan model pembelajaran problem based learning berbasis aplikasi tracker untuk meningkatkan pemahaman konsep fisika. *Journal of Learning and Technology*.
- Dantic, M. J. P., & Fluraon, A. (2022). PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students. *Journal of Science and Education*.
- Dantic, M. J., & Fularon, J. B. (2022). *PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students*. International Journal of Learning, Teaching and Educational Research.
- Diab, H., Daher, W., Rayan, B., & Issa, N. (2024). Transforming science education in elementary schools: The power of PhET simulations in enhancing student learning. *Multimodal Technologies and Interaction*, 8(11), 105.
- Diraya, I., Budiyo, A., & Triastutik, M. (2021). Kontribusi Virtual Lab Phet Simulation untuk Membantu Praktikum Fisika Dasar. *Phenomenon: Jurnal Pendidikan MIPA*, 11(1), 45–56. e-ISSN: 2502–5708
- Dosol-Demonteverde, M. G. (2026). Virtual reality for physics learning: A thematic review. *Lensa: Jurnal Kependidikan Fisika*.
- Fajriati, A., Wisroni, W., & Handrianto, C. (2024). Pemanfaatan Teknologi Artificial Intelligence (AI) dalam Pembelajaran Berbasis Peserta Didik di Era

- Digital. *WAHANA PEDAGOGIKA: Jurnal Ilmiah Pendidikan Dan Pembelajaran*, 6(2), 71–85.
- Febryanti, A. D., & Purwaningsih, E. (2024). Penerapan problem based learning untuk meningkatkan pemahaman konsep fisika. *Jurnal Inovasi Pendidikan Sains*, 5(2), 45–53.
- Hafizah, E., & Nurhaliza, S. (2021). Implementasi problem based learning terhadap kemampuan literasi sains siswa. *Quantum: Jurnal Inovasi Pendidikan Sains*, 12(1), 1–10.
- Hallinger, P. (2021). Tracking the evolution of problem-based learning. *International Journal of Problem-Based Learning*, 15(2).
- Hardani, Auliya, N. H., Andriani, H., Fardani, R. A., Ustiawaty, J., Utami, E. F., Sukmana, D. J., & Istiqomah, R. R. (2020). Metode Penelitian Kualitatif & Kuantitatif. *CV Pustaka Ilmu*.
- Hatika, R. G., Daruwati, I., & Sohibun, S. (2022). Identifikasi miskonsepsi mahasiswa Prodi Pendidikan Fisika Universitas Pasir Pengaraian pada materi listrik statis. *Jurnal Ilmiah Wahana Pendidikan*, 8(23), 393-399.
- Heinich, R., Molenda, M., Russell, J., & Smaldino, S. (2021). *Instructional Media and Technologies for Learning*. Pearson.
- Hernandez, E., Campos, E., Barniol, P., & Zavala, G. (2025). Test of understanding of electric field, force, and flux. *Physical Review Physics Education Research*.
- Hidayat, T., & Khotimah, K. (2022). PEMANFAATAN TEKNOLOGI DIGITAL DALAM KEGIATAN PEMBELAJARAN. *Jurnal Pendidikan*.
- Holmes, W., Bialik, M., & Fadel, C. (2022). *Artificial Intelligence in Education*. Center for Curriculum Redesign.
- Jecha, J., Igwean, C. C., & Banaras, A. (2026). Generative AI and adaptive systems for customising help-seeking scaffolds: A systematic review. *Research Square*.
- Jiao, L., et al. (2024). AI meets physics: A comprehensive survey. *Artificial Intelligence Review*, 57(9), 256.
- Johansson, A. (2022). Visualizations of particle-field interactions.
- Kaniawati, I., et al. (2021). *Implementation of interactive conceptual instruction (ICI) learning model assisted by computer simulation*. *Journal of Physics: Conference Series*.

- Kirabo, E., Batiibwe, M. S. K., Mbulankende, J. S., & Lie, J. (2024). Technology-supported problem-based learning in mathematics education. *SN Social Sciences*.
- Kotsis, K. T. (2025). From chalkboard to chatbot: The future of physics education through artificial intelligence integration. *EIKI Journal of Effective Teaching Methods*.
- Kusuma, A. A. K., Maharani, W. A. D., Wibowo, F. C., & Costu, B. (2024). Effectiveness of artificial intelligence-based physics learning media. *Journal of Physics Education Research*, 19(1), 45–58.
- Latif, E., Liu, V., & Zhai, X. (2026). A systematic review of intelligent and robot tutoring systems: Evolution, pedagogical design, and AI-driven classification. *Smart Learning Environments*.
- Leon. (2025). Student-Created Generative Artificial Intelligence (GenAI) Physics Simulations: A Pedagogical Framework. *IGI Global*.
- Mayer, R. E. (2021). *Multimedia Learning (3rd ed.)*. Cambridge University Press.
- Milasari, D., & Nugraheni, N. (2024). Integrasi Pendidikan Konservasi dan Teknologi untuk Mewujudkan Pendidikan Inklusif dan Berkualitas dalam Pencapaian SDGs. *Jurnal Penelitian Pendidikan Indonesia (JPPI)*, 1(3), 119–125.
- Mnguni, L. (2025). AI as a teaching augmentor: A review of the integration of AI in science education. *Multidisciplinary Reviews*.
- Molamahu, D., et al. (2025). The Influence of the Problem Based Learning (PBL) Model Assisted by PhET Simulation on Students' Learning Outcomes in Parabolic Motion Material. *Kasuari: Physics Education Journal (KPEJ)*, 8(1).
- Mulyadi, S. A., Musyarrofah, W., Ibana, L. I., Suprianto, S., Indrasari, H., & Rahman, K. (2025). Efektivitas Penerapan Model PBL untuk Meningkatkan Kemampuan Pemecahan Masalah Siswa pada Materi Gaya listrik Kelas XI B1 SMAN 2 Pamekasan. *PeTeKa*, 8(3), 1171–1191.
- Nailunada, N., Yuliati, L., & Wisodo, H. (2025). Scientific explanation skills through PBL assisted by PhET simulations. *Kasuari: Physics Education Journal*, 8(1), 10–18.
- Nasya, D. N., & Wibowo, S. (2024). Implementasi chatbot berbasis AI dalam pembelajaran berbasis web. *Jurnal Teknologi Pendidikan*, 26(1), 77–88.
- Nicholus, G., Muwonge, C. M., & Joseph, N. (2023). The role of problem-based learning in physics education. *F1000Research*.

- Nyirahabimana, P., Minani, E., & Nduwingoma, M. (2024). Assessing the impact of multimedia application on student conceptual understanding in quantum physics. *Education and Information Technologies*.
- Ogegbo, A. A., & Ramnarain, U. (2022). *Teaching and learning physics using interactive simulation: A guided inquiry practice*. African Journal of Research in Mathematics, Science and Technology Education.
- Perkins, K., Adams, W., Dubson, M., et al. (2021). PhET: Interactive simulations. *The Physics Teacher*.
- Purnama, I., et al. (2023). *Particle trajectory simulation using Python and spreadsheet as an online learning alternative*. Journal of Physics: Conference Series.
- Rahmawati, R., & Anugrah, Y. W. (2022). Penerapan PBL untuk membenahi pemahaman konsep siswa. *SPEKTRA: Jurnal Pendidikan Sains*, 10(2), 120–128.
- Ramadhani, M. M. (2023). Analisis Strategi Pendidikan Inklusif Berbasis Sains dan Teknologi dalam Mendukung Pencapaian Tujuan Pembangunan Berkelanjutan (SDGs) 2030 di Indonesia. *Seminalu*, 1(1), 433–441.
- Rararati, P. A., Nuroso, H., & Kurniawan, A. F. (2024). Kajian literatur: Penggunaan simulasi phet dalam pembelajaran fisika. *Lontar Physics Today*, 3(2), 045-054.
- Rayan, B., Daher, W., Diab, H., & Issa, N. (2023). Integrating PhET simulations into elementary science education: A qualitative analysis. *Education Sciences*, 13(9), 884.
- Rianti, R., et al. (2026). The Effect of Problem Based Learning Model Assisted by PhET Simulation on Understanding Physics Concepts. *Lensa Jurnal Kependidikan Fisika*, 12(1), 28.
- Rifky, S. (2024). Dampak Penggunaan Artificial Intelligence bagi Pendidikan Tinggi. *Indonesian Journal of Multidisciplinary on Social and Technology*, 2(1), 37–42.
- Rizkita, N. I., & Mufit, F. (2022). Analisis pemahaman konsep siswa pada pembelajaran fisika. *Jurnal Eksakta Pendidikan*, 6(1), 15–22.
- Rochmawati, D. R., Arya, I., & Zakariyya, A. (2023). Manfaat Kecerdasan Buatan untuk Pendidikan. *Jurnal Teknologi Komputer Dan Informatika*, 2(1), 124–134
- Rodriguez, P. A. (2025). Immersive virtual reality simulation of charged particles: Design guidelines and user experience.

- Rodriguez, P. A. (2025). Immersive virtual reality simulation of charged particles: Design guidelines and user experience. Purdue University Thesis.
- Saifullah, S., Yawan, H., Syafitri, N., & Nurhaliza, S. (2024). Integrating AI chatbot into learning management system: Enhancing student engagement and learning outcomes. *International Journal of Educational Technology*, 21(3), 210–225.
- Saparina, S. (2022). Pengembangan e-LKPD berbasis PBL terhadap pemahaman konsep. *Repository Universitas Jambi*.
- Saputri, H. A., et al. (2023). Analisis instrumen asesmen: Validitas, reliabilitas, tingkat kesukaran, dan daya beda butir soal. *Jurnal Didaktik*, 9(2), 123–134.
- Sari, D. P., et al. (2023). Media pembelajaran interaktif. *Jurnal Pendidikan Indonesia*.
- Sary, D. (2026). ANALISIS MISKONSEPSI SISWA PADA MATERI LISTRIK STATIS MENGGUNAKAN METODE CERTAINTY OF RESPONSE INDEX (CRI). *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, 9(1), 27-33.
- Savenko, V., Babichev, S., & Goncharenko, T. (2024). Simulating physical processes in education with Python's tools. *Springer Proceedings*.
- Savin-Baden, M., & Fraser, H. (2023). *Rethinking problem-based learning for the digital age*. Taylor & Francis.
- Senyah, A. O. (2024). Integrative review of problem-based learning in K-12 education.
- Setiawan, B., Fatmah, E. N., Pujiyanto, P., & Wiyatmo, Y. (2023). Development of artificial intelligence (AI)-based physics learning media. *Jurnal Pendidikan Fisika Indonesia*, 19(2), 89–98.
- Shafiq, M., et al. (2025). *Artificial intelligence in physics education: Transforming learning from primary to university level*. Education and Information Technologies.
- Shafiq, M., et al. (2025). Artificial Intelligence in Physics Education: Transforming Learning from Primary to University Level. *Indus Journal of Social Sciences*, 3(1), 717-733.
- Simangunsong, I. T., Uskenat, K., & Gebze, D. A. (2024). Problem Based Learning Berbasis Artificial Intelligence terhadap Kemampuan Berpikir Siswa. *Jurnal Pendidikan Fisika*, 13(1), 41–47.
- Sufyadi, S., Lambas, Rosdiana, T., Novrika, S., Isyowo, S., Hartini, Y., Primadonna, M., Rochim, N. A. F., & Rizal, M. L. (2021). Panduan Pembelajaran dan Asesmen Jenjang Pendidikan Dasar dan Menengah (SD/MI, SMP/MTs, SMA/SMK/MA).

Jakarta: Badan Penelitian dan Pengembangan dan Perbukuan Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Sugiyono. (2021). *Metode penelitian dan pengembangan (Research and Development)*. Alfabeta.

Suherly, T., Azizahwati, A., & Rahmad, M. (2023). Analisis pemahaman konsep siswa dalam pembelajaran fisika. *Jurnal Paedagogy*, 10(1), 55–62.

Sujana, A., & Jayadinata, A. K. (2018). Implementasi problem-based learning dalam pembelajaran IPA. *Jurnal Pendidikan Dasar*.

Sukma, M. D. A., & Diyana, T. N. (2024). Analisis pemahaman konsep fisika siswa. *Jurnal Inovasi Pembelajaran Fisika*, 6(1), 20–28.

Sulisworo, D., & Arslan, A. (2025). Intelligent tutoring systems and the future of problem-solving education: An opinionated synthesis. *Jurnal Genesis Indonesia*.

Suparman, D., Juandi, D., & Tamur, M. (2021). Meta-analysis of problem-based learning in mathematics. *Journal of Physics: Conference Series*.

Suryaningrum, S., Lutfi, S. P., Hayati, M. A., Muktiarni, M. P., Subhan, H. M., Noveny, R. M., ... & Rahayu, S. (2024). Ilmu Pendidikan. *CV Rey Media Grafika*

Taufik, M. (2025). Artificial intelligence for teaching and learning computational physics: A state-of-the-art review of trends, challenges, and future directions. *International Journal of Contextual Science Education*.

Tobing, D. A. L., & Simamora, R. (2026). Pengaruh PBL terhadap pemahaman konsep matematis. *Jurnal Ilmu Pendidikan*, 8(1), 33–40.

Tsakeni, M., Nwafor, S. C., Mosia, M., & Egara, F. O. (2025). Mapping the scaffolding of metacognition and learning by AI tools in STEM classrooms. *Journal of Intelligence*.

Tsvetkova, O., Piatykop, O., Dzherenova, A., & Pronina, O. (2023). Development and implementation of virtual physics laboratory simulations for enhanced learning experience in higher education. *CEUR Workshop Proceedings*.

Tyagi, N. (2025). AI in education: Personalized learning through intelligent tutors. *International Journal of Advanced Research in Computer Science*.

Usenik, A., Kallay, N., & Tomisic, V. (2024). Motion of ions in solution under the influence of an electric field: Microscopic versus macroscopic view. *Journal of Chemical Education*.

- Uwambajimana, S., Minani, E., Mollel, A. D., & Nyirahabimana, P. (2023). *The impact of using PhET simulation on conceptual understanding of electrostatics*. Journal of Mathematics and Science Teacher.
- Vanderburg, R., & Mann, G. (2021). Changing physics instruction by synergizing Vygotskian educational theory and virtual reality. *Journal of Higher Education Theory and Practice*.
- Velychko, V. Y., Kaidan, V. P., & Kaidan, N. V. (2024). The use of computer modeling in the educational process based on the example of studying Coulomb's law. *Journal of Physics: Conference Series*, 2871(1), 012014.
- Verawati, N. N. S. P., Iswara, A., & Wahyudi, W. (2022). Validitas Perangkat Pembelajaran Berbasis Model Kooperatif Tipe Student Facilitator and Explaining (SFAE) untuk Meningkatkan Hasil Belajar Fisika Peserta Didik. *Lensa: Jurnal Kependidikan Fisika*, 10(1), 1–7.
- Vioni, H., Kholilah, D., & Piliang, F. A. (2025). Efektivitas Model Pembelajaran Problem Based Learning (PBL) Berbantuan Lembar Kerja Peserta Didik (LKPD) pada Materi Usaha dan Energi untuk Meningkatkan Hasil Belajar Fisika pada Siswa Kelas X-1 SMA Negeri 3 Padangsidempuan. *Edu Society: Jurnal Pendidikan, Ilmu Sosial dan Pengabdian Kepada Masyarakat*, 5(1), 520–527
- Wahab, A., Junaedi, J., & Azhar, M. (2021). Efektivitas Pembelajaran Statistika Pendidikan Menggunakan Uji Peningkatan N-Gain di PGMI. *Jurnal basicedu*, 5(2), 1039–1045.
- Wati, E., Samsudin, A., & Saepuzaman, D. (2025). Trend of physics learning models in problem solving. *Al-Jabar: Jurnal Pendidikan Fisika*.
- Wendra, F., & Mandriesa, C. (2025). Pengaruh simulasi PhET dan PBL terhadap pemahaman konsep siswa. *Prosiding SEMNASTEKMU*.
- Wulandari, D., & Setiani, R. (2025). Pengaruh Model Problem Based Learning Terintegrasi Literasi Sains untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik Tingkat SMA. *IPF: Inovasi Pendidikan Fisika*, 14(1), 1–5.
- Wulandari, R. (2021). Characteristics and Learning Models of The 21st Century. In *Social, Humanities, and Educational Studies (SHEs): Conference Series*, 4(3), 8–16.
- Younis, A. (2025). Advancing learning outcomes in physics education through artificial intelligence integration.

Zhang, J. (2026). Scaffolding probabilistic reasoning in civil engineering education: Integrating AI tutoring with simulation-based learning. *Education Sciences*, 16(1), 103.

