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Effect of the Use of AI-Assisted Scaffolding on Students' Predicting Skills in Acid-Base Practical Work

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Abstract: Low science process skills among students, particularly in the predicting aspect, indicate that many students still experience difficulties in anticipating experimental outcomes based on scientific concepts and evidence. This study aimed to examine the implementation of Artificial Intelligence (AI)-assisted cueing scaffolding techniques and investigate their effect on students' predicting ability in deep learning through acid-base laboratory activities at SMA Negeri 13 Kota Jambi. The study employed a mixed-methods approach using a Sequential Explanatory design, with the quantitative phase adopting an Only Posttest Control Group Design. The research sample consisted of two classes: an experimental class receiving guided inquiry learning integrated with AI-assisted cueing scaffolding, and a control class receiving guided inquiry learning with direct teacher guidance. Data were collected using science process skills observation sheets focusing on the predicting indicator and essay tests, and were analyzed using the Mann–Whitney test. The findings revealed that AI-assisted cueing scaffolding was successfully implemented across three learning sessions following the guided inquiry stages. Students in the experimental class demonstrated a gradual improvement in predicting ability and achieved higher average scores than those in the control class. Statistical analysis showed an Asymp. Sig. (2-tailed) value of < 0.001, indicating a significant difference between the two groups. The novelty of this study lies in integrating AI-assisted cueing scaffolding into deep learning-based guided inquiry during acid-base laboratory activities to enhance students' predicting skills. It can be concluded that AI-assisted cueing scaffolding is effective in improving students' ability to predict, an essential component of science process skills. These findings provide an innovative instructional alternative for chemistry learning and may serve as a reference for integrating AI-based scaffolding strategies into other science topics to strengthen students' higher-order thinking and scientific reasoning.

Keywords: Acids and Bases; Artificial Intelligence (AI); Predicting; Scaffolding; Science Process Skills.

Introduction

To innovate and meet the challenges of the digital era, the education sector must strike a balance between teaching methods, learning processes, and curriculum requirements. Law Number 20 of 2003 concerning the National Education System in Indonesia emphasizes the importance of education that is high-quality, inclusive, and adaptive to global developments. [1]. Curriculum implementation should be student-centered and employ practices and innovative learning strategies capable of fostering meaningful knowledge, thereby overcoming rote-learning approache.

Meaningful learning is a component of deep learning. The deep learning approach emphasizes profound and meaningful understanding, enabling students to apply knowledge in real-life situations rather than merely memorizing it [2]. The primary goal of this approach is to ensure that students not only grasp the core of a concept but are also able to connect it to relevant practical contexts in real life [3]. The deep learning framework initiated by the Ministry of Basic and Secondary Education is grounded in three instructional approaches: mindful, meaningful, and joyful learning [4]. One of the intended learning outcomes of implementing deep learning is enhancing students' science process skills.

Science process skills are abilities frequently practised during scientific inquiry [5]. This means that these skills are applied during the process of discovering scientific knowledge. There are eight indicators of science process skills (SPS): observing, classifying variables, formulating problems, formulating hypotheses, designing experiments, processing data, applying concepts, and communicating [6]. These eight indicators assist students in thinking systematically and logically to solve problems through scientific steps; consequently, science learning focuses not merely on the resulting knowledge, but also on the process of acquiring that knowledge itself [7]. Thus, possessing these eight science process skills leads to positive learning outcomes.

Indicates that students' science process skills such as observing, formulating hypotheses, planning experiments, interpreting data and graphs, predicting, applying concepts, and communicating remain low. Skills in interpreting graphs and communicating were the weakest among students, with mastery levels ranging from only 20% to 50% across certain indicators; consequently, these areas require special attention from teachers.[8]. These findings align with observations and interviews conducted with a chemistry teacher at SMAN 13 Kota Jambi on Thursday, October 23, 2025, which revealed that students' science process skills were low, characterized by limited ability to carefully observe phenomena, identify relevant variables, formulate

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hypotheses, and communicate experimental data. Furthermore, some students reported a lack of confidence when conducting practical activities and tended to wait for teacher instructions. addressing these low science process skills requires the use of instructional models such as Problem-Based Learning (PBL), discovery learning, and inquiry learning[9].

The inquiry learning model is a process that emphasizes students' direct experience and active participation, engaging their full potential to learn in a systematic, critical, logical, and analytical manner while grasping various concepts and principles[10]. The guided inquiry model highlights student engagement through activities such as formulating questions, developing hypotheses, conducting investigations, collecting and processing data, and communicating results [11]. Indicates that inquiry learning has not yet been fully effective; suboptimal implementation and insufficient student engagement have resulted in less-than-ideal learning outcomes [12]. Therefore, a supporting strategy, specifically the scaffolding technique, is required.

Scaffolding, introduced by Vygotsky through the concept of the Zone of Proximal Development (ZPD) involves the provision of temporary support by a teacher or via assistive tools to help students independently accomplish challenging tasks [13]. The specific types of scaffolding developed include questioning, prompting, cueing, and explaining. These techniques are particularly well-suited for simple laboratory activities, as they can enhance students' science process skills [14]. In a scaffolding-based learning environment, teachers use questioning to guide critical thinking, prompting to sustain thought processes, cueing to provide hints on key concepts, and explaining to clarify concepts that students do not yet grasp; these techniques facilitate active learning and a gradual progression toward deeper understanding. Implementing scaffolding strategies within the SiMaYang learning model positively influenced students' science process skills in chemistry education [15]. However, in practice, teachers' manual implementation of scaffolding is often constrained by time limitations; this is where artificial intelligence, specifically AI models like GPT (Generative Pre-trained Transformer), can play a role by providing rapid, tailored guidance, hints, and explanations tailored to individual students' needs.

Artificial intelligence (AI) possesses the ability to mimic human thought and learning processes by analyzing vast amounts of data. One rapidly evolving application of AI is GPT (Generative Pre-trained Transformer). A key benefit of GPT AI is its capacity to simulate human interaction and generate human-like text; this capability is particularly valuable for creating intelligent tutoring systems that provide students with real-time support and feedback [16]. A reciprocal collaboration between human intelligence and artificial intelligence can enhance the capabilities of both, leading to more effective and meaningful educational experiences [17]. The use of AI fosters adaptive and innovative learning, enabling it to serve as a digital assistant for students during their studies, including practical work in chemistry.

Through laboratory work, students gain firsthand experience in observing chemical phenomena and conducting experiments [18]. Acid-base chemistry is a suitable subject for such practical activities, as it is closely linked to daily life; many substances around us exhibit acidic or basic properties. Therefore, this study aims to investigate the impact of AI-assisted scaffolding techniques on students' predictive abilities during in-depth acid-base laboratory learning. The study's novelty lies in applying AI-assisted scaffolding in this context to enhance students' science process skills, specifically their ability to make predictions. By combining scaffolding with AI, the study introduces an adaptive learning support approach that is rarely implemented in high school chemistry education. It is expected that this research will offer an innovative instructional alternative that fosters the development of students' science process skills.

Research Methods

This study employed a mixed-methods approach using a sequential explanatory design. In the first phase, quantitative data were collected and analyzed to examine the effect of AI-assisted cueing scaffolding on students' predicting skills. In the second phase, qualitative data obtained from classroom implementation observations were analyzed to explain and strengthen the interpretation of the quantitative findings. The integration of the two datasets occurred during the interpretation stage, where qualitative findings were used to explain the statistical results. The quantitative component employed a posttest-only control group design.

Table 1. Posttest-Only Control Group Design.

Group	Treatment	Posttest
Experiment	X	O
Control	Y	O

Information:
X : Guided inquiry learning integrated with AI-assisted cueing scaffolding
Y : Guided inquiry learning with direct teacher guidance
O : Posttest measuring students' predicting skills

The posttest-only control group design involved two groups: an experimental group and a control group. The experimental group received guided inquiry learning integrated with AI-assisted cueing scaffolding, whereas the control group received guided inquiry learning with direct teacher guidance. At the end of the intervention, both groups completed a posttest in the form of an essay test to assess students' predicting skills. Classroom implementation observations were conducted during the learning process to document students' learning behaviors and instructional implementation. These qualitative findings were subsequently used to support and explain the quantitative results.

The study population consisted of all Grade XI Science students at SMA Negeri 13 Kota Jambi during the 2025/2026 academic year. Purposive sampling was employed based on the similarity of students' academic achievement and classroom characteristics. The final sample consisted of two classes. Grade XI Science 5 (n = 34) served as the experimental group and received guided inquiry learning integrated with AI-assisted cueing scaffolding. Grade XI Science 4 (n = 34) served as the control group and received guided inquiry learning with direct teacher guidance.

Quantitative data were collected using essay tests that measured students' predicting skills, whereas qualitative data

were obtained from classroom implementation observation sheets documenting students' learning activities and instructional implementation. Quantitative data were analyzed using normality and homogeneity tests. Because one dataset was not normally distributed, hypothesis testing was conducted using the Mann–Whitney U test. Qualitative data obtained from classroom observations were analyzed descriptively and integrated with the quantitative findings during the interpretation stage to explain differences in students' predicting skills between the two groups.

Results and Discussion

Implementation Observation Instrument

This study was conducted at SMAN 13 Kota Jambi during the even semester of the 2025/2026 academic year, involving Grade XI (Phase F) students. The research utilised two classes, XI Science 5 as the experimental group and XI Science 4 as the control group, with 34 students in each. Distinct treatments were applied to each class to examine science process skills on the topic of acids and bases: the experimental class received AI-assisted scaffolding (using cueing techniques) within a guided inquiry model, while the control class received guided inquiry learning with direct teacher guidance within the same model. The study presents data derived from lesson implementation observation sheets and post-tests (essay format) administered to both groups.

Based on observations from three sessions on acids and bases, an improvement in students' science process skills, specifically the "predicting" indicator, was evident in both the experimental and control classes. However, the improvement observed in the experimental class was greater than that in the control class. In the experimental class, students utilized AI-assisted cueing scaffolding. During the first session, students were still adjusting to the AI tool, and some struggled to formulate questions and construct hypotheses relevant to the problem at hand. By the second session, students had become accustomed to the AI-provided cues, leading to improved hypothesis formulation. In the third session, the majority of students were able to formulate problems and construct hypotheses more independently and logically, in alignment with the concepts being studied. Meanwhile, in the control class, which employed a guided-inquiry model with direct teacher supervision, students also demonstrated improvement across sessions. However, throughout the learning process, they relied heavily on teacher guidance to construct their hypotheses. Although student performance improved by the third session, the quality of their questions and the accuracy of their hypotheses remained lower than those of the experimental class.

Table 2. Combined Results of Implementation Observation Sheets

Session	Experiment	Control
1	Students are still adapting to AI-assisted cueing scaffolding. Regarding the prediction indicator, the hypotheses formulated remain simple and are not yet fully grounded in relevant concepts.	Students still require significant guidance from the teacher in formulating hypotheses; the hypotheses they have developed do not yet fully align with the given problem.
2	Students are becoming accustomed to using AI assistance in the learning process. They are beginning to formulate more accurate hypotheses by connecting their prior knowledge with the problems presented.	Students' ability to formulate hypotheses has improved compared to the previous session. However, some students still require teacher guidance to construct appropriate hypotheses.
3	Students have become capable of formulating hypotheses independently and with greater accuracy. The majority of students can construct logical hypotheses based on the concepts they have learned. Group discussions have become more active with the aid of AI as a learning support tool.	The students demonstrated improvement in formulating hypotheses. However, some students still relied on teacher guidance to provide supporting reasons for their hypotheses; consequently, their results were not yet as good as those of the experimental class.

Overall, observational results indicate that implementing AI-assisted cueing-based scaffolding in the experimental class effectively enhanced students' science process skills, particularly the indicators of asking questions and making predictions, compared to instruction in the control class. Observations spanning the first to the third session revealed significant improvement in the "predicting" indicator for students in both the experimental and control classes. However, the improvement observed in the experimental class was more consistent and substantial than in the control class, demonstrating the effectiveness of the cueing-based scaffolding intervention.

The classroom observation findings provide qualitative evidence supporting the quantitative analysis presented in the following section. The progressive improvement in students' participation, independence, and ability to formulate predictions observed during the learning process is consistent with the differences in posttest performance between the experimental and control groups.

These results indicate that implementing AI-assisted cueing scaffolding enables students to develop their predictive skills more effectively than direct-guidance instruction. Scaffolding can enhance science process skills by providing graduated assistance until students are capable of independent learning[19]. Explained that the scaffolding approach helps students gain a deeper understanding of concepts through support tailored to their specific learning needs[20]. In this study, AI serves as a source of assistance, providing hints, guidance, and feedback throughout the learning process. AI-assisted scaffolding does not simply provide answers but facilitates students in organizing prior knowledge, interpreting evidence, and constructing logical

predictions through continuous guidance. Such adaptive support enables learners to develop deeper conceptual understanding and stronger reasoning abilities[21]. Through graduated cues, students were guided to activate their prior knowledge, connect scientific concepts to experimental observations, and develop hypotheses through logical reasoning. As the level of support was gradually reduced, students became more confident and independent in generating predictions during laboratory activities. This learning process explains why the experimental group achieved higher predicting skills than the control group. These findings are consistent with Vygotsky's Zone of Proximal Development (ZPD), which posits that students achieve higher levels of understanding when appropriate support is provided within that zone. In this study, AI-assisted cueing scaffolding served as adaptive support by providing graduated hints rather than direct answers, allowing students to progressively construct scientific reasoning and improve their prediction skills.

The results of this study align with previous research indicating that the application of scaffolding in inquiry-based learning can help enhance students' science process skills by providing guidance that is administered gradually according to their learning needs [22]. demonstrates that scaffolding within inquiry-based learning can improve students' science process skills [23]. Thus, it can be concluded that the application of the cueing scaffolding technique within the guided inquiry learning model significantly enhances students' science process skills.

Essay Test (Post-test)

Based on data from essay tests assessing students' science process skills, specifically the "predicting" indicator, across three sessions, the results indicate that students in the experimental class experienced a more significant improvement in these skills compared to the control class, particularly regarding the ability to make predictions. In the unit on acids and bases, students in the experimental class demonstrated greater precision in observing litmus paper reactions to determine solution properties, measuring pH, and relating solution properties and pH values to everyday life. The implementation of scaffolding through cueing techniques provided graduated support, enabling students to develop their skills in predicting outcomes from available data, as shown in Table 3.

Table 3. Cumulative Average Post-test Scores for Sessions 1 through 3 in Both Classes

Class	Session	Average	Percentage (%)
Experiment	1	2	66.6
	2	2.3	76.6
	3	2.6	86.6
Average		2.3	77
Control	1	1.3	43.3
	2	1.7	56.6
	3	1.8	60
Average		1.6	53

Normality testing in this study employed the Shapiro-Wilk test. This method was selected due to the relatively small sample size of fewer than 50 respondents, totalling 34 students. The Shapiro-Wilk test is used for small sample sizes. The Shapiro-Wilk test is used to assess data normality for small samples, specifically those with fewer than 50 respondents[24].

Table 4. Normality Test Results

	Shapiro-Wilk		
	Statistic	df	Sig.
Experiment	.953	34	.154
Control	.930	34	.032

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Based on the data in Table 4, the significance value for the experimental class was 0.154, while the significance value for the control class was 0.032. According to the decision-making criteria for the normality test, the data for the experimental class are considered normally distributed because the significance value is greater than 0.05. Conversely, the data for the control class are considered not normally distributed because the obtained significance value is less than 0.05. This indicates that the assumption of normality for the entire research dataset was not fully met; therefore, hypothesis testing in this study was conducted using a non-parametric test.

In this study, homogeneity testing was performed using Levene's Test. This test operates by comparing the deviation of each group's values from their central value and subsequently analyzing the variance and these deviations.

Table 5. Homogeneity Test Results

		Sig.
Score	Based on Mean	.668
	Based on Median	.554
	Based on Median and with adjusted df	.554
	Based on trimmed mean	.655

Based on the data in Table 5, the results obtained in the based-on-mean section have a significance value of 0.668. This indicates that the homogeneity test results show equal variances (homogeneous) because the significance value is greater than 0.05. Thus, H_0 is accepted, and H_1 is rejected. Meeting the assumption of homogeneity indicates that the differences observed in the research results stem not from differences in variance between groups, but rather from the applied treatment. Hypothesis testing was conducted using the Mann–Whitney test, a non-parametric test for two independent samples. Statistically, the Mann-Whitney test results in Table 6 show a p-value <0.001 (<0.05), indicating a significant difference between the two groups. This reinforces the conclusion that the improvement in predictive ability observed in the experimental group resulted from implementing the AI-assisted cueing scaffolding technique. The use of this non-parametric test also aligns with the characteristics of the research data, thereby yielding a more accurate conclusion. To determine the practical significance of the intervention, the effect size was calculated using the formula $r = Z/\sqrt{N}$. Based on the Mann–Whitney test results ($Z = -4.388$; $N = 68$), the effect size was 0.53, indicating a large effect according to Cohen's criteria. This finding suggests that AI-assisted cueing scaffolding had not only statistical significance but also substantial educational significance in improving students' predicting skills.

Table 6. Mann-Whitney test results

	Result
Mann-Whitney U	221.000
Wilcoxon W	816.000
Z	-4.388
Asymp. Sig. (2-tailed)	<.001
a. Grouping Variable: kode_2	

Overall, the implementation of AI-assisted cueing scaffolding proved more effective than direct teacher guidance in improving students' predicting skills. This aligns with research indicating that scaffolding provides learning support that helps students overcome difficulties during the learning process, fostering greater engagement and confidence while enabling them to develop their learning skills independently [25]. The improvement in science process skills observed in the experimental class stemmed from students receiving assistance in the form of hints, guiding questions, and feedback delivered incrementally through the cueing technique. This support helped students grasp the steps of scientific inquiry without being given the answers outright, thereby allowing them to remain actively engaged in constructing their own knowledge. Although the improved performance of the experimental group can largely be attributed to AI-assisted cueing scaffolding, it is also possible that the guided inquiry learning model contributed to students' active engagement during laboratory activities. Therefore, the observed improvement likely resulted from the complementary interaction between guided inquiry and adaptive AI-assisted scaffolding rather than from the AI intervention alone.

Conclusion

The implementation of an AI-assisted scaffolding technique within a guided inquiry model successfully enhanced students' predictive abilities during an in-depth study of acid-base practical work. Students in the experimental class demonstrated greater engagement, independence, and self-confidence compared to those in the control class. Furthermore, the AI-assisted scaffolding technique had a significant impact on students' predictive abilities. These findings demonstrate that AI-assisted cueing scaffolding is not only statistically effective but also pedagogically meaningful. The strategy promotes independent scientific reasoning, encourages active participation in chemistry laboratory activities, and offers an innovative instructional approach to improving students' prediction skills in guided inquiry learning.

Author's Contribution

N.A Rani: Contributed as the first author by designing the research, implementing the AI-assisted cueing scaffolding intervention, collecting and analyzing quantitative and qualitative data, interpreting the findings, and preparing the manuscript. M.H.E Hasibuan: Contributed as the principal research supervisor by providing guidance on the research design, methodology, data analysis, interpretation of the findings, and critical revision of the manuscript. F. Romundza: Contributed as the co-supervisor by providing academic guidance during the research process, reviewing the data analysis, and revising the manuscript to improve its scientific quality. Asrial & F. Ekaputra: Contributed by providing scientific input on the research methodology, reviewing the manuscript, and offering suggestions to improve the quality and clarity of the article.

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References

[1] Sisdiknas, *Undang-Undang Sisdiknas (Sistem Pendidikan Nasional): UU RI No. 20 Tahun 2003*, 1st ed. Jakarta: PT. Sinar Grafika, 2008.

[2] A. W. Sari *et al.*, "Implementasi Deep Learning : Suatu Inovasi Pendidikan," vol. 13, no. 01, 2025.

[3] A. A. Wijaya, T. Haryati, and E. Wuryandini, "Implementasi Pendekatan Deep Learningdalam Peningkatan Kualitas Pembelajaran di SDN 1 Wulung, Randublatung, Blora," *Indones. Res. J. Educ.*, vol. Volume 5, no. Nomor 1, p. Halaman: 451–457, 2025.

[4] Kemendikdasmen, *Pembelajaran Mendalam.* Pusat Kurikulum dan Pembelajaran, 2025.

[5] M. Senisum, "Keterampilan Proses Sains Siswa Sma Dalam Pembelajaran Biologi," *J. Pendidik. dan Kebud. Missio*, vol. 13, no. 1, pp. 76–89, 2021, doi: 10.36928/jpkm.v13i1.661.

[6] F. Ahmad and N. I. Sari, "Keterampilan Proses Sains (KPS) Mahasiswa Akademi Farmasi pada Mata Kuliah Kimia Dasar," *Venn J. Sustain. Innov. Educ. Math. Nat. Sci.*, vol. 4(1), no. ISSN: 2964-867X, pp. 28–36, 2025.

[7] N. Y. Rustaman, *KETERAMPILAN PROSES SAINS*. Bandung: UNIVERSITAS PENDIDIKAN INDONESIA PRESS, 2007.

[8] Siswanto, Yusiran, and M. F. Fajarudin, "Keterampilan Proses Sains Dan Kemandirian Belajar Siswa: Profil Dan Setting Pembelajaran Untuk Melatihkannya," *Gravity J. Ilm. Penelit. dan Pembelajaran Fis.*, vol. Vol. 2 No., no. ISSN 2442-515x, e-ISSN 2528-1976, pp. 190–202, 2016.

[9] P. M. Sari, S. L. Handayani, and Nurwahyuni, "The Comparison of the Effect of Different Types of Learning Models on Science Process Skills of Pre-Service Elementary School Teacher," *Didakt. J. Pendidik. Sekol. Dasar*, vol. Volume 3, no. p-ISSN: 2716-1722 e-ISSN: 2715-8128, pp. 121–128, 2020.

[10] R. Jundu, P. H. Tuwa, and R. Seliman, "Hasil belajar IPA Siswa SD di Daerah Tertinggal dengan penerapan model pembelajaran inkuiri terbimbing," *Sch. J. Pendidik. Dan Kebudayaan,* vol. 10(2), pp. 103–111, 2020.

[11] S. Wahyuni, "implementasi model pembelajaran inquiry terbimbing untuk meningkatkan keterampilan proses sains anak usia dini," *J. Cahaya Mandalika*, vol. 4 (2), no. P-ISSN: 2809-0543 E-ISSN: 2809-5955, pp. 339–346, 2023.

[12] H. Fitriani and L. Firdaus, "Penerapan Model Pembelajaran Inkuiri Terbimbing Untuk Meningkatkan Keterampilan Proses Sains Dan Hasil Belajar Kognitif Siswa," *J. Ilm. IKIP Mataram*, vol. Vol. 7, No, no.

ISSN: 2355-6358, 2020.
[13] J. Zumbach, C. Ortler, I. Deibl, and S. Moser, "Using prompts to scaffold metacognition in case-based problem solving within the domain of attribution theory.," *J. Probl. Learn.*, vol. 7(1), pp. 21–31, 2020.
[14] D. Fisher and N. Frey, *Guided instruction: How to develop confident and successful learners*. ASCD. www.ascd.org/books, 2010.
[15] R. D. Aprian, S. Sunyono, and T. Efkar, "Pengaruh Strategi Scaffolding pada Pembelajaran SiMaYang dalam Meningkatkan Keterampilan Proses Sains.," *J. Pendidik. Dan Pembelajaran Kim.*, vol. 6(1), 1396, 2017.
[16] M. Zafari, J. S. Bazargani, A. Sadeghi-Niaraki, and S.-M. (2022). Choi, "Artificial Intelligence Applications in K-12 Education: A Systematic Literature Review.," *IEEE Access*, vol. 10, pp. 61905–61921, 2022, doi: https://doi.org/10.1109/ACCESS.2022.3179356.
[17] M. H. BAYSHA and E. R. Puj. ASTUTI, "optimalisasi pembelajaran teknologi pendidikan dengan bantuan gpt AI," *EDUTECH J. Inov. Pendidik. Berbantuan Teknol.*, vol. Vol. 4 No., no. E-ISSN : 2797-0140 P-ISSN : 2797-0590, 2024.
[18] Y. Amakraw and N. Kartika, "Strategi Implementasi Praktikum Pembelajaran Ilmu Pengetahuan Alam Untuk Siswa Sekolah Dasar dan Menengah 1Pendidikan Biologi, Institut Agama Islam Negeri," *Sci. Educ. Res. J. Progr. Stud. Tadris IPA, IAIN Sorong https//e-jurnal.iainsorong.ac.id/index.php/jaser*, 2022.
[19] A. Rahmasiwi, "Peningkatan keterampilan proses sains siswa dalam pembelajaran biologi melalui penerapan model pembelajaran inkuiri di kelas XI MIA 9 (ICT) SMA Negeri 1 Karanganyar tahun pelajaran 2014/2015," 2015.
[20] D. P. Ningrum, M. Budiyanto, and E. Susiyawati, "Penerapan model pembelajaran guided inquiry dengan LKPD berbasis scaffolding untuk melatihkan keterampilan proses sains siswa.," *Pensa E-Jurnal Pendidik. Sains*, vol. 9(3), pp. 399–406, 2021.
[21] B. R. Belland, A. E. Walker, and N. J. Kim, "A Bayesian Network Meta-Analysis to Synthesize the Influence of Contexts of Scaffolding Use on Cognitive Outcomes in STEM Education," *Rev. Educ. Res.*, vol. 87, no. 6, pp. 1042–1081, 2017, doi: 10.3102/0034654317723009.
[22] S. K. Handayanto, S. Fawaiz, and A. Taufiq, "Using E-Scaffolding To Develop Students' Scientific Reasoning Through Inquiry-Based Learning," *Obraz. i Nauk.*, vol. 26, no. 3, pp. 69–90, 2024, doi: 10.17853/1994-5639-2024-3082.
[23] S. Tiaradipa, I. Lestari, M. H. Effendi, and M. Rusdi, "The Development of Scaffolding in Inquiry-Based Learning to Improve Students' Science Process Skills in The Concept of Acid and Base Solution," *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 5, no. 2, p. 211, 2020, doi: 10.20961/jkpk.v5i2.42420.
[24] Z. Rahman, A. A. Suparto, and F. Jaya, "Pengaruh Media Pembelajaran Berbasis Game Edukasi Quizizz Terhadap Motivasi Belajar Peserta Didik," *J. Komput. Teknol. Inf. Sist. Inf.*, vol. 4, no. 3, pp. 1772–1779, 2025, doi: 10.62712/juktisi.v4i3.530.
[25] Adinda Adinda, Sisi Mulia, Irfan Irfan, and Gusmaneli Gusmaneli, "Penerapan Strategi Pembelajaran Scaffolding Dalam Membentuk Kemandirian Peserta Didik," *J. Bima Pus. Publ. Ilmu Pendidik. Bhs. dan Sastra*, vol. 2, no. 2, pp. 34–41, 2024, doi: 10.61132/bima.v2i2.763.