JTK: Jurnal Tadris Kimiya 10, 2 (December 2025): 246-255
Website: http://journal.uinsgd.ac.id/index.php/tadris-kimiya/index
ISSN 2527-9637 **(online) ISSN** 2527-6816 **(print)**

Enhancing Creative Thinking in Electrochemistry through a Science Literacy Integrated STEM-PBL Model

Ani Sutiani* [1*], Ratu Evina Dibyantini* [1]*, Mutiara Agustina Nst.* [1]*, and Dwy Puspita Sari* [1]

[1]Department of Chemistry Education, Faculty of Mathematics and Natural Sciences
Universitas Negeri Medan, Medan, 20221, Indonesia
[*]E-mail: anisutiani@unimed.ac.id

Received: December 2025; Accepted: December 2025; Published: December 2025

Abstract

Creative thinking is an essential learning outcome in undergraduate chemistry education, particularly in electrochemistry, where students are required to integrate conceptual understanding with problem solving and real world applications. Integrating science literacy within a Science, Technology, Engineering, and Mathematics–Problem Based Learning (STEM-PBL) framework offers a practical instructional approach to address this challenge by situating electrochemical concepts in authentic problem contexts. This study analysed the effectiveness of a science literacy integrated STEM-PBL model in enhancing undergraduate students' creative thinking skills in an electrochemistry course. A quantitative quasi experimental design was employed, involving an experimental group taught using the science literacy integrated STEM-PBL model and a control group receiving traditional instruction. Students' creative thinking skills were measured before and after instruction using a validated assessment instrument. Instructional effectiveness was evaluated by comparing normalized gain (N-gain) scores between the two groups. The results show that students who participated in the STEM-PBL learning environment achieved a substantially higher N-gain score (75.47%) than those in the control group (49.96%). These findings indicate that integrating science literacy into STEM-PBL activities significantly enhances students' creative thinking skills in electrochemistry learning. The results have important implications for chemistry instruction. They suggest that incorporating science literacy oriented, problem based STEM activities can provide instructors with an effective strategy to promote creative thinking and deepen students' understanding of electrochemical concepts. This approach may support the design of more engaging and meaningful electrochemistry learning experiences in undergraduate chemistry classrooms.

Keywords: chemistry education, creative thinking skills, science education, science literacy, STEM-PBL

DOI: https://doi.org/10.15575/jtk.v10i2.41486

1. Introduction

In the context of 21st-century education, higher education institutions are required to cultivate essential competencies, particularly the 4C skills—critical thinking, creative thinking, collaboration, and communication (Rahmawati et al., 2019). To meet these demands, innovative instructional approaches are necessary, one of which is the integration of STEM (Science, Technology, Engineering, and Mathematics) in learning. STEM-based instruction enables engagement with fundamental scientific concepts through real-life contexts and supports the development of skills needed to address complex interdisciplinary and global challenges (Muttaqiin, 2023; Li et al., 2020).

Among the 4C skills, creative thinking is increasingly recognized as a key competency that allows individuals to approach scientific problems innovatively and apply knowledge in unfamiliar contexts (Henriksen et al., 2021; Runco & Acar, 2012). Research indicates that creative thinking in chemistry can be effectively fostered through active engagement and problem-solving processes, including hypothesis formulation, experimental design, and critical analysis of results—skills essential for advancing innovation in sustainable energy and environmental chemistry (Long et al., 2022). In electrochemistry, abstract concepts such as electron transfer mechanisms, electrochemical thermodynamics, and the design of batteries and fuel cells demand creative thinking to connect theory with practice and generate innovative solutions to real-world problems (Ramos & Padilla, 2025).

Despite its relevance, electrochemistry learning at the university level remains largely focused on conceptual explanations and algorithmic problem solving, limiting opportunities to cultivate higher-order thinking skills. This condition also affects the development of scientific literacy, a core outcome of science education. Scientific literacy provides individuals with the ability to critically engage with scientific and technological issues and make well-informed decisions. Science-literate individuals are expected to understand scientific concepts, communicate scientific issues, integrate knowledge across disciplines, and apply scientific reasoning in everyday life (Widhyastuti, 2017; Wahyu et al., 2020; Suparya et al., 2022; Shwartz et al., 2006 in Cahyana et al., 2019; Snow & Dibner, 2016; Rohmaya, 2022; Faridah et al., 2022). However, scientific literacy in the Indonesian educational context remains relatively low, as indicated by national and institutional-level studies, underscoring the need for instructional strategies and learning materials that explicitly support scientific literacy development (Kimianti & Prasetyo, 2019; Hasasiyah et al., 2020; Mabsutsah et al., 2021).

To address these challenges, Problem-Based Learning (PBL) is particularly effective for complex topics such as electrochemistry, as it places learners at the center of the learning process through engagement with authentic, real-world problems. PBL encourages active knowledge construction rather than passive content acquisition while fostering critical thinking, collaboration, and innovative problem-solving skills (Saputra, 2019; Mayasari et al., 2022). Through structured inquiry stages—including problem identification, investigation, data analysis, and reflection—PBL supports the development of scientific reasoning and lifelong learning competencies (Manalu & Kurniawati, 2024; Dwita & Hidayati, 2022; Rahmadani et al., 2023).

Furthermore, STEM education integrates science, technology, engineering, and mathematics to equip learners with both soft and hard skills required to address real-world and global challenges (Hermansyah, 2020; Committee on Highly Successful Schools or Programs in K 12 STEM, & Education; National Research Council, 2019; Rahmawati et al., 2022). STEM approaches have been widely implemented across disciplines and educational levels, demonstrating positive effects on problem-solving ability, conceptual understanding, and critical thinking (Adiwiguna et al., 2019; Gunawan & Shieh, 2020; Khairani et al., 2018; Ritonga & Zulkarnain, 2021; Irma et al., 2020; Yasifa et al., 2023). In science education, STEM is closely aligned with addressing environmental and societal issues, reinforcing its relevance and applicability (Supriyatun, 2019; Ningsyih et al., 2020; Haritun & Utaminingsih, 2023; Nurjumiati et al., 2023; Anggriani et al., 2024).

The integration of STEM education, scientific literacy, and Problem-Based Learning forms a comprehensive framework for fostering creative thinking in electrochemistry learning. This integrated approach promotes interdisciplinary reasoning, authentic problem engagement, and higher-order thinking by linking theoretical understanding with technological and societal applications (Hmelo-Silver, 2004; Pinar et al., 2025). In line with Marchak et al. (2021), STEM-PBL–oriented chemistry instruction that integrates collaborative inquiry and hands-on problem-solving effectively enhances creative thinking and scientific reasoning, while cultivating a sustained inquiry mindset essential for future scientific careers. Although previous studies have examined STEM-PBL and STEM-PjBL implementations (Anggraini & Huzaifah, 2017; Muttaqiin, 2023), research focusing on STEM integration through diverse instructional tools and learning resources in electrochemistry remains limited, indicating a clear research gap that warrants further investigation.

2. Research Method

2.1. Research Design

This study employed a quasi-experimental research design using a pretest–posttest control group design. This design was selected to examine the effectiveness of a science literacy–integrated STEM-PBL learning model in improving students' creative thinking skills in electrochemistry while maintaining natural classroom conditions. The use of a quasi-experimental approach was considered appropriate due to practical and ethical considerations that limit random assignment of participants (Budiyono, 2017).

2.2. Participants

The research was conducted from May to November 2024 in the Chemistry Education Program, Universitas Negeri Medan. The population consisted of all fourth-semester undergraduate students enrolled in the electrochemistry course. Two intact classes were selected as the research sample, involving a total of 88 students. One class (44 students) was assigned as the experimental group, while the other class (44 students) served as the control group.

2.3. Learning Treatment

The experimental group received instruction using a science literacy–integrated STEM-PBL learning model, which combined interdisciplinary STEM principles with problem-based learning activities and science literacy tasks. Learning activities were structured around real-world electrochemistry problems that required students to analyze phenomena, design solutions, interpret data, and justify conclusions using scientific reasoning.

The control group was taught using conventional instructional methods, which primarily involved lecturer explanations, textbook-based learning, and routine problem-solving exercises without explicit integration of STEM or science literacy components.

2.4. Instrumentation

Students' creative thinking skills were measured using a creative thinking skills test developed based on five indicators: fluency, flexibility, originality, elaboration, and problem solving. The instrument consisted of 20 multiple-choice items, with each indicator represented by four items. The test was administered as a pretest before the learning intervention and as a posttest after the completion of the instructional sessions.

Prior to implementation, the instrument was reviewed by chemistry education experts to ensure content validity, and item analysis was conducted to confirm its reliability and suitability for measuring creative thinking skills in the context of electrochemistry learning.

2.5. Data Analysis

Data analysis was carried out by calculating students' learning improvement using the normalized gain (N-Gain) formula. The N-Gain scores were categorized to determine the effectiveness of the learning model. Before conducting inferential statistical analysis, normality tests (Kolmogorov–Smirnov) and homogeneity tests (Levene's test) were performed to ensure that the data met the assumptions required for parametric testing.

To determine whether there was a significant difference in creative thinking skill improvement between the experimental and control groups, an Independent Samples t-test was conducted using the N-Gain scores at a significance level of $\alpha = 0.05$.

3. Result and Discussion

In light of the test results, the students' critical thinking skills were assessed using the

Independent Samples Test. Following the determination of the N-Gain scores for the control and experimental classes, tests for data homogeneity and normality were performed. A summary of the experimental and control groups' N-Gain scores in Table 1.

With a maximum N-Gain of 91.67 and a low of 58.82, the experimental class's average %N-Gain, classified as effective, is 75.47, as indicated in Table 1. On the other hand, the control group's N-Gain average was 49.96, with a maximum of 64.71 and a low of 33.33.

Table 1. Table of N-Gain scores for the control and experimental classes

	Control Class	Experimental Class
Pretest mean	24.09	25.57
Postest mean	62.27	81.11
% N-Gain	49.96	75.47
N-Gain min	33.33	58.82
N-Gain max	64.71	91.67

The STEM-PBL learning paradigm in the Basic Chemistry course is successful in raising student learning outcomes and developing their capacity for creative thought, according to the statistics presented. This is consistent with a research by Ningsih (2020) that found that combining STEM with the Problem-Based Learning (PBL) approach can increase student engagement and learning results by 75%.

Following the use of the Problem-Based Learning model with a STEM (science, technology, engineering, and mathematics) approach, the students' creative thinking skills also satisfied the level of "good," scoring 47.84 out of 60. When STEM-PBL is used to teach, it also has a substantial impact on improving student understanding. Furthermore, pupils' conceptual understanding is influenced by their starting skills (Wulandari, 2022). The results of creative thinking skills can also be visible in Figure 1.

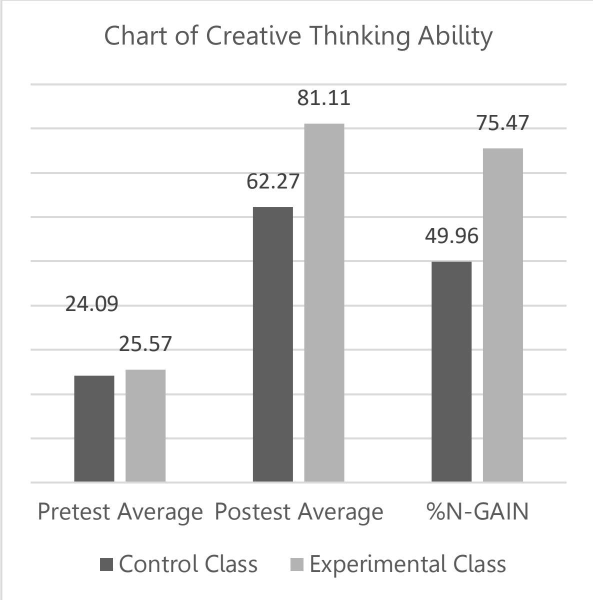

Figure 1. Chart of Creative Thinking Ability

To ascertain the differences in creative thinking skills between the control and experimental groups, an Independent Sample Test was then performed based on the N-Gain results for the control and experimental classes. the fluency and elaboration indicators demonstrated higher improvement compared to the other indicators. The higher N-Gain values for fluency and elaboration can be attributed to the learning process, which provided more opportunities for students to generate multiple ideas and develop their responses in detail. In contrast, the flexibility, originality, and problem-solving indicators require more complex higher-order thinking skills, resulting in relatively lower levels of improvement. The test results are shown in Table 2.

Table 2. Normality test results

	Class	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
N-Gain	Control	.117	44	.154
	Experimental	.104	44	.200*

The study's sample population consisted of 88 people, which is greater than 50. Thus, the Kolmogorov Smirnov test was used to determine whether the data was normal. Based on test findings for the control class, which revealed a sig value of 0.154 > 0.05, the data is deemed normal. The experimental class data has a sig value of 0.200 > 0.05, which indicates that the data is normal. Furthermore, a sig value was obtained by testing for data homogeneity using Levene's Test for Equality. It may be concluded that the variance data and N-Gain for the two classes are same and homogeneous because 0.154 > 0.05.

As a result, the independent t test for the N-gain score is guided by the sig. in the Equal variances assumed table. The STEM-PBL Integrated Science Literacy model and Direct Instruction learning of Electrochemistry material in the Basic Chemical Science course differ significantly in terms of effectiveness (real). The "Independent Sample Test" results on table 3 demonstrate that the STEM-PBL Integrated Science Literacy approach is more successful in fostering students' capacity for creative thought, especially when it comes to electrochemical content.

Table 3. Independent Samples Test results

	t	df	Sig. 2-tailed
N-Gain	-16.659	86	.000

Based on Table 3, the analysis yielded a t-value of −16.659, with 86 degrees of freedom (df) and a two-tailed significance value (Sig. = 0.000). Since the significance value is less than 0.05 ($p < 0.05$), the null hypothesis (H_0) is rejected. This indicates that there is a statistically significant difference in the mean N-Gain scores between the two groups being compared.

The negative t-value suggests that the mean N-Gain score of the control group is lower than that of the experimental group, based on the order of group entry in SPSS. This result implies that the experimental group achieved a significantly higher learning gain than the control group.

These results validate the research conducted by Cahyaningsih and Ghufron (2016). The findings can be explained through the integrated PBL–STEM–science literacy framework. The PBL structure engaged students in authentic, open-ended problems that stimulated inquiry and divergent thinking, thereby supporting creative cognitive processes (Ningsih, 2020). STEM integration further expanded students' solution spaces by requiring the coordination of scientific concepts, engineering design, and mathematical reasoning, which encouraged flexibility and originality. At the same time, the emphasis on science literacy guided students to evaluate evidence and justify ideas scientifically, ensuring that creativity remained within disciplinary boundaries (Cahyaningsih & Ghufron, 2016). Together, these elements worked synergistically to activate and regulate students' creative thinking. The study's findings imply that applying the problem-based learning (PBL) paradigm can enhance students' capacity for independent and creative thought when studying mathematics. The study's findings demonstrate that PBL is more effective than conventional teaching techniques at fostering students' critical thinking and creativity. Misla & Mawardi (2020) found that while students were solving mathematical problems, the problem-based learning (PBL) learning model was more effective than the problem-solving learning model at enhancing their critical thinking abilities. PBL considerably enhanced students' critical thinking abilities more than problem solving, according to the t test study.

Fahrurrozi et al. (2022) The results of this study offer an intriguing highlight, demonstrating that the STEM-PBL learning approach not only supports but also encourages students' critical thinking skills in citizenship education courses. In addition to serving as a guide, STEM-PBL develops a learning path that encourages students to actively participate in each learning phase and provides a space for unrestricted creativity and exploration. As a result, this study supports the idea that STEM-PBL not only instructs but also creates a learning environment where students can move to the beat of understanding and discovery. The effectiveness of the problem-based learning (PBL) learning paradigm in fostering students' critical thinking abilities is highlighted by Kartikasari et al. (2021). The improvement demonstrated by the increase in average grades and satisfying learning accomplishment levels attests to the fact that PBL is not only a useful teaching strategy but also a powerful instrument for fostering students' critical development. As a result, this study paints a favourable picture of PBL's beneficial effects on raising study standards and student academic performance.

The findings indicate a significant improvement in students' creative thinking skills following the implementation of the integrated STEM–PBL learning intervention complemented by science literacy tasks. This improvement was observed across multiple dimensions of creativity, particularly originality, flexibility of ideas, and the ability to generate scientifically plausible solutions. These results are consistent with previous studies reporting that interdisciplinary STEM learning fosters divergent and flexible thinking (Bybee, 2013; English, 2016). The problem-based learning (PBL) framework further contributed to these outcomes by situating the learning process within authentic and meaningful problem contexts. Students demonstrated more active engagement in learning, along with increased persistence and motivation when addressing complex biological challenges. These findings align with prior research suggesting that science literacy and argumentation practices serve as cognitive scaffolds that guide creativity while maintaining disciplinary boundaries (OECD, 2018). Overall, the results demonstrate that the integrated implementation of STEM learning, problem-based instruction, and science literacy activities effectively enhances students' creative thinking by promoting originality without compromising scientific validity. These findings provide empirical support for the use of interdisciplinary, problem-centered instructional designs as effective strategies for developing creative thinking skills in science education.

4. Conclusion

Based on the findings of this study, it can be concluded that creative thinking skills can be effectively enhanced through the application of appropriate instructional models aligned with course content. The science literacy–integrated STEM-PBL learning model proved to be effective in improving students' creative thinking skills in electrochemistry. By situating electrochemical concepts within authentic, interdisciplinary, and real-world problem contexts, this approach fosters both deep conceptual understanding and essential creative problem-solving abilities. As higher education continues to evolve in response to contemporary scientific and societal challenges, educators are encouraged to adopt integrative learning models such as STEM-PBL to better prepare students with critical, creative, and innovative competencies. These skills are not only crucial for academic success but also for addressing global challenges related to sustainability, energy, and environmental issues.

References

Adiwiguna, S., Dantes, N., & Gunamantha, M. (2019). Pengaruh model problem based learning (PBL) berorientasi stem terhadap kemampuan berpikir kritis dan literasi sains siswa Kelas V SD di Gugus I Gusti Ketut Pudja. PENDASI: *Jurnal Pendidikan Dasar Indonesia, 3*(2), 94-103. https://doi.org/10.23887/jpdi.v3i2.2871

Anggraini, F. I., & Huzaifah, S. (2017). Implementasi STEM dalam pembelajaran IPA di sekolah menengah pertama. *In Seminar Nasional Pendidikan IPA Tahun 2021*, *1*(1), 722-731. Retrieved from: https://conference.unsri.ac.id/index.php/semnasipa/article/view/738

Anggriani, L. A., Hasnawati, H., & Nurhasanah, N. (2024). Development of ethnoscience-based teaching materials in class V elementari school. *Insights:*

Journal of Primary Education Research, 1(1), 1-10. https://doi.org/10.59923/insights.v1i1.68

Budiyono. (2017). *Pengantar metodologi penelitian pendidikan*. Surakarta: UNS Press.

Bybee, R. W. (2013). *The case for STEM education: challenges and opportunities.* United States: National Science Teachers Association Press.

Cahyana, U., Supatmi, S., & Rahmawati, Y. (2019). The influence of web-based learning and learning independence toward student's scientific literacy in chemistry course. *International Journal of Instruction, 12*(4), 655-668. https://doi.org/10.29333/iji.2019.12442a

Cahyaningsih, U., & Ghufron, A. (2016). Pengaruh penggunaan model problem based learning terhadap karakter kreatif dan berpikir kritis dalam pembelajaran matematika. *Jurnal Pendidikan Karakter*, *7*(1), 104–115. https://doi.org/10.21831/jpk.v0i1.10736

Committee on Highly Successful Schools or Programs in K 12 STEM, & Education; National Research Council. (2019). Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. Washington, D.C.: The National Academies Press.

Dwita, E. G., & Hidayati, Y. M. (2021). Model pembelajaran problem based learning berbasis video pembelajaran untuk mengembangkan kemampuan pemecahan masalah matematika. *Jurnal basicedu, 6*(4), 5868-5876. https://doi.org/10.31004/basicedu.v6i4.3145

English, L. D. (2016). STEM education K–12: perspectives on integration. *International Journal of STEM Education, 3*(1), 1–8. https://doi.org/10.1186/s40594-016-0036-1

Fahrurrozi, F., Sari, Y., & Fadillah, J. (2022). Studi literatur : pemanfaatan model problem based learning terhadap kemampuan berpikir kritis dalam pembelajaran PKn siswa sekolah dasar. *Edukatif : Jurnal Ilmu Pendidikan, 4*(3), 4460–4468. https://doi.org/10.31004/edukatif.v4i3.2795

Faridah, U., Rahayu, Y. S., & Dewi, S. K. (2022). Pengembangan e-modul interaktif untuk melatihkan keterampilan literasi sains siswa materi transpor membran. *Berkala Ilmiah Pendidikan Biologi (BioEdu), 11*(2), 394–404. https://doi.org/10.26740/bioedu.v11n2.p394-404

Gunawan, S., & Shieh, C. J. (2020). Effects of the application of stem curriculum integration model to living technology teaching on business school students' learning effectiveness. *Contemporary Educational Technology, 12*(2), 1–7. https://doi.org/10.30935/cedtech/8583

Haritun, N., & Utaminingsih, R. (2023). Upaya peningkatan hasil belajar peserta didik melalui model pembelajaran problem based learning pada pembelajaran tematik muatan IPA kelas V SD Negeri Surokarsan 2 Yogyakarta. *Science Education and Development Journal Archives, 1*(2), 57–62. https://doi.org/10.59923/sendja.v1i2.56

Hasasiyah, S. H., Hutomo, B. A., Subali, B., & Marwoto, P. (2020). analisis kemampuan literasi sains siswa SMP pada materi sirkulasi darah. *Jurnal Penelitian Pendidikan IPA, 6*(1), 5–9. https://doi.org/10.29303/jppipa.v6i1.193

Henriksen, D., Creely, E., Henderson, M., & Mishra, P. (2021). Creativity and technology in teaching and learning: a literature review of the uneasy space of implementation. *Educational Technology Research and Development, 69*(4), 2091-2108. https://doi.org/10.1007/s11423-020-09912-z

Hermansyah, H. (2020). Pembelajaran IPA berbasis STEM berbantuan ICT dalam meningkatkan keterampilan abad 21. *Jurnal Ilmiah Profesi Pendidikan, 5*(2), 129–132. https://doi.org/10.29303/jipp.v5i2.117

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational Psychology Review, 16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Irma, Z. U., Kusairi, S., & Yuliati, L. (2020). Penguasaan konsep siswa pada materi fluida statis dalam pembelajaran stem disertai e-formative assessment. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan, 5*(6), 822-827. https://doi.org/10.17977/jptpp.v5i6.13638

Kartikasari, I., Nugroho, A., & Muslim, A. H. (2021). Penerapan model PBL untuk meningkatkan kemampuan berpikir kritis siswa pada kelas IV sekolah dasar. *Jurnal Gentala Pendidikan Dasar, 6*(l), 44–56. https://doi.org/10.22437/gentala.v6i1.10124

Khairani, K., Mukhni, M., & Aini, F. Q. (2018). Pembelajaran berbasis stem dalam perkuliahan kalkulus di perguruan tinggi. *Uninus Journal of Mathematics Education and Science (UJMES), 3*(2), 104-111. https://doi.org/10.30999/ujmes.v3i2.544

Kimianti, F., & Prasetyo, Z. K. (2019). Pengembangan e-modul IPA berbasis problem based learning untuk meningkatkan literasi sains siswa. *Kwangsan: Jurnal Teknologi Pendidikan, 7*(2), 91–103. http://dx.doi.org/10.31800/jtp.kw.v7n2.p91--103

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: a systematic review. *International Journal of STEM Education, 7*(1), 1–16. https://doi.org/10.1186/s40594-020-00207-6

Long, H., Kerr, B., Emler, T., & Birdnow, M. (2022). A critical review of assessments of creativity in education. *Review of Research in Education, 46*(1), 288–323. https://doi.org/10.3102/0091732X221084326

Mabsutsah, N., Sudarti, & Subchan, W. (2021). Analisis kemampuan literasi sains siswa SMP ibrahimy 3 pada isu pencemaran lingkungan di pelelangan ikan mimbo. *Jurnal Pendidikan MIPA, 11*(2), 29–36. https://doi.org/10.37630/jpm.v11i2.471

Manalu, V. E. C., & Kurniawati, D. (2024). Pengembangan modul berbasis problem based learning (PBL) terintegrasi STEM materi kesetimbangan kimia fase F kelas XI. *Jurnal Pendidikan Tambusai, 8*(2), 28976–28984. Retrieved from: https://jptam.org/index.php/jptam/article/view/18684

Marchak, D., Shvarts-Serebro, I., & Blonder, R. (2021). Teaching chemistry by a creative approach: Adapting a teachers' course for active remote learning. *Journal of Chemical Education, 98*(9), 2809–2819. https://doi.org/10.1021/acs.jchemed.0c01341

Mayasari, A., Arifudin, O., & Juliawati, E. (2022). Implementasi model problem based learning (PBL) dalam meningkatkan keaktifan pembelajaran. *Jurnal Tahsinia, 3*(2), 167–175. https://doi.org/10.57171/jt.v3i2.335

Misla, M., & Mawardi, M. (2020). Efektifitas pbl dan problem solving siswa SD ditinjau dari kemampuan berpikir kritis. *Jurnal Ilmiah Sekolah Dasar, 4*(1), 60-65. https://doi.org/10.23887/jisd.v4i1.24279

Muttaqiin, A. (2023). Pendekatan STEM (science, technology, engineering, mathematics) pada pembelajaran ipa untuk melatih keterampilan abad 21. *Jurnal Pendidikan MIPA, 13*(1), 34–45. https://doi.org/10.37630/jpm.v13i1.819

Ningsih, S. (2020). Penerapan model pembelajaran PBL terintegrasi STEM untuk meningkatkan aktivitas dan hasil belajar peserta didik di kelas XII IPA 5 SMAN 7 Padang. *Pillar of Physics Education*, *13*(3), 443-450. http://dx.doi.org/10.24036/9893171074

Ningsyih, S., Yulianci, S., Adiansha, A. A., Nurjumiati, N., & Asriyadin, A. (2020). Efektifitas media pembelajaran IPA berbasis masalah untuk meningkatkan kreativitas mahasiswa calon guru SD. *Jurnal Pendidikan MIPA, 10*(1), 12–15. https://doi.org/10.37630/jpm.v10i1.285

Nurjumiati, N., Yulianci, S., Hidayatullah, P., Suryaningsih, S., & Fuadi, M. (2023). Pengembangan Media Pembelajaran Lectora Inpire untuk Meningkatkan Pemahaman Siswa pada Mata Pelajaran IPA SD. *Science Education and Development Journal Archives, 1*(2), 77–81. https://doi.org/10.59923/sendja.v1i2.58

OECD (2018). *PISA for Development Assessment and Analytical Framework: Reading, Mathematics and Science*. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264305274-en

Pinar, F. I. L., Panergayo, A. A. E., Sagcal, R. R., Acut, D. P., Roleda, L. S., & Prudente, M. S. (2025). Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: a meta-analysis. *Disciplinary and Interdisciplinary Science Education Research, 7*(1), 1-17. https://doi.org/10.1186/s43031-025-00137-9

Purwaningrum, J. P. (2016). Mengembangkan kemampuan berpikir kreatif matematis melalui discovery learning berbasis scientific approach. *Refleksi Edukatika, 6*(2), 145–157. https://doi.org/10.24176/re.v6i2.613

Rahmadani, A., Ariyanto, A., Rohmah, N. N. S., Hidayati, Y. M., & Desstya, A. (2023). Model problem based learning berbasis media permainan monopoli dalam meningkatkan pemahaman siswa sekolah dasar. *Jurnal Ilmiah Pendidikan Citra Bakti, 10*(1), 127-141. https://doi.org/10.38048/jipcb.v10i1.1415

Rahmawati, M. A., Agustin, A., Ridwan, E., Erdawati, D., Darwis, R., & Rafiuddin. (2019) The development of chemistry students' 21 century skills through a STEAM project on electrolyte and non-electrolyte solutions. *Journal of Physics: Conference Series, 1402*(5), 1-6. https://doi.org/10.1088/1742-6596/1402/5/055049

Rahmawati, L., Juandi, D., & Nurlaelah, E. (2022). Implementasi STEM dalam meningkatkan kemampuan berpikir kritis dan kreatif matematis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 11*(3), 2002-2014. https://doi.org/10.24127/ajpm.v11i3.5490

Ramos-Mejía, A., & Padilla, K. (2025). A problem-based learning electrochemistry course for undergraduate students to develop complex thinking. *Education Sciences, 15*(3), 320. https://doi.org/10.3390/educsci15030320

Ritonga, S., & Zulkarnain, Z. (2021). Penerapan pendekatan STEM untuk meningkatkan keterampilan berpikir kritis peserta didik. *Jurnal Studi Guru dan Pembelajaran,* *4*(1), 75–81. https://doi.org/10.30605/jsgp.4.1.2021.519

Rohmaya, N. (2022). Peningkatan literasi sains siswa melalui pembelajaran ipa berbasis socioscientific issues (SSI). *Jurnal Pendidikan MIPA, 12*(2), 107–117. https://doi.org/10.37630/jpm.v12i2.553

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal, 24*(1), 66–75. https://doi.org/10.1080/10400419.2012.652929

Saputra, H. (2020). Pembelajaran berbasis masalah (problem based learning). 1-9. https://doi.org/10.17605/OSF.IO/GD8EA

Snow, C. E., & Dibner, K. A. (2016). Science literacy: concepts, contexts, and consequences. Washington: National Academies Press. https://doi.org/10.17226/23595.

Suparya, I. K., I Wayan Suastra, & Putu Arnyana, I. B. (2022). Rendahnya literasi sains: faktor penyebab dan alternatif solusinya*. Jurnal Ilmiah Pendidikan Citra Bakti,* *9*(1), 153–166. https://doi.org/10.38048/jipcb.v9i1.580

Supriyatun, S. E. (2019). Implementasi pembelajaran sains, teknologi, engineering, dan matematika STEM pada materi fungsi kuadrat. JUMLAHKU: Jurnal Matematika *Ilmiah STKIP Muhammadiyah Kuningan, 5*(1), 80–87. https://doi.org/10.33222/jumlahku.v5i1.567

Wahyu, Y., Suastra, I. W., Sadia, I. W., & Suarni, N. K. (2020). The effectiveness of mobile augmented reality assisted STEM-based learning on scientific literacy and students' achievement. *International Journal of Instruction, 13*(3), 343–356. https://doi.org/10.29333/iji.2020.13324a

Westwood, P. (2020). Inclusive and Adaptive Teaching: Meeting the challenge of diversity in the classroom. London: Routledge. https://doi.org/10.4324/9781032723594

Widhyastuti, M. (2017). *Pengaruh kemampuan literasi sains terhadap kreativitas siswa smp pada tema siklus*. Thesis, Faculty of Mathematics and Natural Sciences: Universitas Negeri Semarang. Retrieved from: https://lib.unnes.ac.id/32499/

Wulandari, P. A., I. W. Dasna, & Nazriati (2022). STEM-PBL and its effect on improving students' concept understanding in high school chemistry learning. *Proceedings Of The 5th International Conference On Learning Innovation,* 135-139. Malang: University of Malang.

Yasifa, A., Hasibuan, N. H., Siregar, P. A., Zakiyah, S., & Anas, N., (2023). Implementasi pembelajaran STEM pada materi ekosistem terhadap kemampuan berpikir kritis peserta didik*. Journal on Education,* *5*(4), 11385–11396. https://doi.org/10.31004/joe.v5i4.2081