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Implementation of Project-Based Learning: Impact on Metacognitive Awareness and Student Learning Outcomes on Corrosion Materials

Dian Anisa Rokhmah Wati[1*], Retno Eka Pramitasari[1], Noer Af'idah[2] ,Roudhoutul Aulia Rochim[2], Rahma Ramadhani[3], Fajar Satriya Hadi[1], Ahmad Bashri[4]

[1] Mechanical Engineering, Engineering Faculty, Hasyim Asy'ari Tebuireng Jombang University, Indonesia.
[2] Science Education, Education Faculty, Hasyim Asy'ari Tebuireng Jombang University, Indonesia.
[3] Mathematics Education, Education Faculty, Hasyim Asy'ari Tebuireng Jombang University, Indonesia.
[4] Biology Education, Faculty of Mathematics and Natural Sciences, Surabaya State University, Indonesia.

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Corresponding Author:
Dian Anisa Rokhmah Wati
dianrokhmahwati@unhasy.ac.id

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Abstract: The research problem is that students often memorize science concepts without deep understanding, leading to low metacognitive awareness and an inability to solve new problems like corrosion topics. This study aims to measure improvement in metacognitive awareness and cognitive learning outcomes through Project-Based Learning (PjBL). The research method is that a quasi-experimental method with a one-group pretest-posttest design was employed. The participants were fourth-semester mechanical engineering students at UNHASY. Data were collected using a metacognitive awareness questionnaire and a cognitive learning test, administered before and after the PjBL intervention. The data were analyzed quantitatively using a Paired Sample T-Test to determine the significance of the differences between the pretest and posttest scores for both metacognitive awareness and learning outcomes. The research results showed significant improvement in both metacognitive awareness ($t=4.70$, $p<0.05$) and learning outcomes ($t=4.87$, $p<0.05$). It is concluded that Project-Based Learning is an effective instructional model for fostering metacognitive awareness and improving academic achievement in science education. Its implementation is highly recommended to develop higher-order thinking skills and deeper conceptual understanding.

Keywords: Learning outcome; MAI; Metacognition; PjBL

Introduction

Learning science, especially chemistry, requires an approach that focuses not only on mastering concepts but also on developing higher-order thinking skills, including metacognition. Metacognition refers to a person's awareness and control of their own learning process, as explained by Ramadhanti et al. (2021) Metacognition in cognitive psychological theory is seen as a form of awareness about one's cognition, how one's cognition works, and how to regulate it, where the former involves our awareness of our thought processes, particularly our declarative knowledge about our memory (Harrison et al., 2018). Developing metacognitive awareness is a crucial learning skill, which leads learners to become more effective and autonomous; since, being conscious of how you learn, helps you identify the most effective ways of doing so (Louca, 2019).

In the context of chemistry learning, students need planning, monitoring, and evaluating cognitive strategies (Andini et al., 2021; Syahmani et al., 2021). This

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is because usually students often face difficulties in understanding abstract concepts such as corrosion, which involves complex electrochemical reactions and applications in everyday life. Students' low metacognitive awareness makes it difficult for them to identify misconceptions and adjust learning strategies. Therefore, a learning approach is needed that can train metacognitive skills while deepening conceptual understanding. Thus, learning models are needed to improve metacognition.

One of the learning models that is considered effective for improving metacognition is Project Based Learning (PjBL) (Mulyani et al., 2021). PjBL is a real project-based learning approach that requires students to design, implement, and reflect on their learning process (Lukitasari et al., 2021). Thus, enjoyable learning can have a positive impact on students. If the learning process is perceived to lack interaction between students and lecturers, it will negatively affect student grades. Since the learning process is an activity aimed at improvement transitioning from not knowing to knowing, from not understanding to comprehending the subject matter, and from being unable to analyse to being capable of independent analysis selecting an appropriate instructional model is essential to achieve this objective. The implications of PjBL are that is improves student engagement, curiosity, creativity, critical thinking, and scientific skills in secondary school physics (Aliati et al., 2025).

In the context of corrosion material, PjBL can be applied through investigative projects such as analyzing the factors causing corrosion in metals or designing prevention methods. Through this project, students not only learn chemical concepts, but also develop metacognitive skills, such as: Planning – determining the steps to complete the project. Monitoring – evaluating understanding during the experiment and Evaluation – reflecting on the results and difficulties encountered (Andini et al., 2021). Several previous studies have shown that PjBL is effective in improving students' metacognitive abilities (Mulyani et al., 2021) and increasing student's learning outcomes and motivations (Hannah et al., 2024) . For example, previous research has shown that students who learn through PjBL show a significant increase in metacognitive awareness compared to traditional learning (Zhang et al., 2021). However, there is still little research that specifically examines the implementation of PjBL on corrosion material and its impact on metacognitive skills. In fact, this material has great potential to be developed into contextual projects, such as case studies of corrosion in industry or the environment.

Furthermore, a challenge in chemistry learning is students' lack of awareness of the importance of metacognition. They tend to memorize concepts without understanding their own learning process. As a result, when faced with new problems, such as explaining corrosion phenomena in real life, students struggle to apply their knowledge, such as how corrosion rates are generally calculated using the weight loss method and electrochemical methods. The weight loss method measures the weight loss that occurs after a certain immersion time. The weight loss method is often used on an industrial and laboratory scale due to its simple equipment and relatively accurate results (Ompusunggu et al., 2020).

Project-Based Learning (PjBL) can be a solution because it provides an inquiry-based learning experience, where students actively construct knowledge through exploration and reflection.

Based on the description above, this study aims to measure the improvement in students' metacognitive awareness through project-based learning on corrosion, and to determine students' learning outcomes on corrosion through project-based learning. The results of this study are expected to contribute to the development of learning strategies that not only improve conceptual understanding but also foster students' independent learning through a metacognitive approach.

Method

Research Design

This study using a quasi-experimental design with a one-group pretest-posttest design. Based on Cook (1979) in Abraham et al. (2022) Quasi-experiments are defined as experiments that have treatments, impact measurements, experimental units but do not use random assignment to create comparisons in order to conclude changes caused by the treatment. This design was chosen due to the researcher's limited ability to use a control class, so the focus was on observing improvements in one group given the treatment. Research design scheme:

O_1 --- X --- O_2

Description:

O_1: Pretest to measure initial abilities.

X: Treatment in the form of implementing the Project-Based Learning (PJBL) model on corrosion material.

O_2: Post test to measure learning outcomes after the treatment.

Research Participants (Sample)

The sample of this research consists of fourth-semester Mechanical Engineering students at Hasyim Asy'ari University (UNHASY) in the academic year 2024/2025 taking the course corrosion technique. Sampling technique is purposive sampling, where all members of the population are sampled. The core principle of purposive sampling is the deliberate selection of participants based on specific characteristics or criteria relevant to the research question. Purposive sampling is a targeted research method where the investigator intentionally selects a specific group of participants who possess particular characteristics directly relevant to the study's goals (Lenaini, 2021; Nyimbili et al., 2024). In this research on Project-Based Learning (PjBL) for corrosion materials, this means the sample consists solely of a defined group of students from a specific engineering class who have all completed the PjBL module. This approach is chosen because it efficiently provides in-depth, "information-rich" data from exactly the right participants who have experienced the intervention, allowing for a focused analysis of how PjBL impacted their metacognitive awareness and learning outcomes, rather than aiming to represent.

Research Variables

This research consists of independent and dependent variables. The independent variable is the factor that the researcher deliberately changes or manipulates to see if it has an effect. It is the presumed "cause". In this research, the independent variable is Project-Based Learning (PjBL) Model for corrosion. A dependent variable is the factor that is measured, it is the outcome that may or may not change in response to the manipulation of the independent variable. It is the presumed "effect". The dependent variable in this research are Metacognitive Awareness and Cognitive Learning Outcomes for corrosion.

Data Collection Instruments

Data were collected using two main instruments. First, to measure student's level of metacognitive awareness used adapted from the Metacognitive Awareness Inventory questionnaire developed by Schraw (1994) and modified to suit the context of engineering students and project-based learning including items in eight metacognitive components, namely: 1) Declarative Knowledge; 2) Procedural Knowledge; 3) Conditional Knowledge; 4) Planning; 5) Information Management Strategies; 6) Comprehension Monitoring; 7) Debugging Strategies, and 8) Evaluation (Hindun et al., 2020), Using a Likert scale (1-5). The data collection method was that the questionnaire was given to groups before (O_1) and after (O_2) treatment.

The second data source was a learning outcome test (Pretest–Posttest) to measure students' cognitive learning outcomes. The pretest and posttest questions were parallel (same difficulty level and material coverage, but the question numbers were randomized). A pretest and posttest measurement of subject attributes in two categories was performed at the beginning as well as after the experiment when the group changed their position (Sirotová et al., 2021). The data collection method was that both instruments were administered twice to the same group, first in the pretest (O_1) given before the treatment began and the posttest (O_2) given after the treatment was completed.

Data Analysis

For Metacognitive Awareness and learning outcomes, data were analyzed using a normality test on the distribution of the total scores of the pretest and posttest MAI questionnaires using the Shapiro-Wilk Test. For the hypothesis test, if the data are normally distributed, use a Paired Sample t-test was used to compare the pretest and posttest. If the data are not normally distributed, the non-parametric Wilcoxon Signed Rank Test was used. The interpretation was as follows; (1) if the Sig. (2-tailed) value is < 0.05, then there is a significant increase in metacognitive awareness after the PjBL model is implemented. And (2) if the Sig. (2-tailed) value is < 0.05, then there is a significant increase in learning outcomes after the PjBL model is implemented.

Result and Discussion

The Improvement of Metacognitive Awarenss through Project-Based Learning (PjBL)

The hypotheses of this experiment are (1) Ho = there is no difference between the learning outcomes of corrosion before and after the implementation of PjBL on corrosion material. H1 = there is a difference between the learning outcomes of corrosion before and after the implementation of PjBL on corrosion material. (2) Ho = There is no difference between metacognitive awareness before and after the implementation of PjBL on corrosion material and H1 = there is a difference between metacognitive awareness before and after the implementation of PjBL on corrosion material.

The quantitative approach is generally used in research that aims to test a particular theory or hypothesis by measuring variables that can be calculated objectively (Aliati et al., 2025). The results of hypothesis testing can be seen below.

Table 1. Tests of Normality Metacognitive Awareness

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Metacognitive Awareness Pretest	.13	12	.20*	.94	12	.52
Metacognitive Awareness Postest	.20	12	.19	.93	12	.43

a. Lilliefors Significance Correction

A normality test is conducted to determine whether the data to be analyzed are normally distributed or not (Anderha et al., 2021). The presented results from the Tests of Normality indicate that the data for both the Metacognitive Awareness pretest and posttest can be considered normally distributed, thus meeting a fundamental assumption for subsequent parametric statistical analyses. This conclusion is primarily based on the Shapiro-Wilk test, which is the more reliable test for the small sample size (n=12) in this study. For the pretest scores, the Shapiro-Wilk test yielded a significance value (p-value) of .526, which is substantially greater than the common alpha level of .05. Similarly, for the posttest scores, the significance value was .433, also well above the .05 threshold. These high p-values lead to a failure to reject the null hypothesis (Ho) for both tests, meaning there is insufficient evidence to suggest that the data deviates from a normal distribution. The supporting Kolmogorov-Smirnov test results, with significance values of .200 (pretest) and .195 (posttest). also support this conclusion. Therefore, H_0 is accepted and H_1 is rejected.

Table 2. Paired Samples Test of Metacognitive Awareness

	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Postest - Pretest	4.17	3.07	4.70	11	.001

The results of the paired-samples t-test revealed a statistically significant increase in metacognitive awareness scores following the intervention. The analysis indicated a mean improvement of 4.17 points from the pretest to the posttest. This observed difference was found to be highly significant, t (11) = 4.702, p = .001. The associated standard deviation of 3.07 for the difference scores indicates a moderate degree of variability in individual participant gains around this mean improvement. The highly significant p-value, which falls well below the standard alpha level of .05, provides strong evidence to reject the null hypothesis. Therefore, it can be concluded that the increase in metacognitive awareness was not due to random chance but is instead a substantial and statistically significant effect, likely attributable to the implemented intervention (PjBL). This is in line with theoretical research which states that metacognitive awareness is indicated to be related to one's academic achievement (Hindun et al., 2020) and Project-based learning as a comprehensive teaching approach that engages students in cooperative and ongoing inquiry activities (Agusdianita, 2023), in which corrosion learning students are asked to plan, observe, and evaluate, which is part of metacognitive awareness.

The results of this study indicate a significant improvement in student's metacognitive awareness after the implementation of the Project-Based Learning (PjBL) model. This improvement is evident in students' ability to plan learning strategies, monitor understanding, and evaluate their learning processes and outcomes more independently and effectively. These findings indicate that the PjBL model is not only effective in achieving cognitive objectives but also has great potential in developing metacognitive awareness to developing metacognitive skills, which are the foundation for lifelong learning.

The Improvement of Student Learning Outcomes on Corrosion Material through Project-Based Learning (PjBL)

The results of the analysis of student learning outcomes on corrosion material, which can be seen in the following table.

Table 3. Tests of Normality Learning Outcomes Corrosion Material

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.19	12	.20*	.88	12	.08
Posttest	.13	12	.20*	.95	12	.64

The normality test using pretest and posttest values showed that the pretest learning outcome data had a significance value of 0.087. Since this value is greater than 0.05, the pretest data are normally distributed.

Similarly, the posttest learning outcome data had a significance value of 0.642, which is greater than 0.05, indicating that the posttest data are also normally distributed. Because the data are normally distributed, further testing is carried out in the form of is a paired sample test.

Table 4. Paired t Test of Learning Outcome Corrosion Material

Pair	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Posttest – Pretest	15.00	10.66	4.87	11	.00

The results of the t-test analysis show a significance value of 0.000 with a calculated t-value of 4.874. With df = 11, the critical t-table value is 2.201. Since the calculated t-value (4.874) is greater than the t-table value (2.201) and the significance value is less than 0.05, there is a significant difference in learning outcomes before and after the implementation of the Project-Based Learning (PjBL) model. In other words, PJBL has a significant effect on learning outcomes. This indicates that the PJBL model is effective in improving students' learning outcomes.

This finding is consistent with previous studies that state PjBL can enhance learning outcomes (Azhari et al., 2023; Chaniago et al., 2024). The improvement in learning outcomes aligns with research conducted by Nurhadiyati et al. (2020), which showed that pretest and posttest data in experimental groups indicated an increase in learning outcomes. PjBL can improve students' learning outcomes because its goal is to provide direct problem-solving experiences and to develop critical thinking skills (Agusdianita, 2023). This result inline to the results clearly point to a noteworthy and affirmative link showing that when PjBL is used, students get better at thinking critically and also do better in their social studies classes (Wulandari et al., 2025).

It is related to the fact that the stages in PjBL have a close and direct correlation with the development of various aspects of metacognitive awareness, namely (1) Planning, this stage directly trains declarative knowledge (knowing what to do) and procedural knowledge (knowing how to do it) from metacognition. Students must formulate the problem, set goals, and design a strategy and timeline for completing the project. This process forces them to map their prior knowledge and plan the effective use of resources. (2) Execution/Doing, this stage is closely related to self-regulation and conditional knowledge (knowing when and why a strategy is used) (Harrison et al., 2018; Siqueira et al., 2020). Throughout the project, students constantly monitor their progress, encounter unexpected challenges, and must make real-time strategy adjustments. This monitoring activity is at the heart of metacognitive skills. (3) Assessment and Reflection: this stage is the culmination of metacognitive training, particularly in the evaluation aspect. Students not only assess the final product but also reflect on the entire learning process. They evaluate what worked, what didn't, what they learned, and how they can improve their performance in the future. This reflection explicitly develops self-evaluation skill (Singh et al., 2023). It was in line with conclusion from experiment that using the Project-Based Learning model or PjBL, in that education can cultivate a positive attitude among students, influencing both their ingenuity and academic achievements, as this method fosters imaginative, ground-breaking, and enjoyable educational experiences that are particularly beneficial to learners (Setiawan et al., 2023).

This is also supported by the characteristics of the corrosion material itself, which is a type of science material that is suitable for using the PjBL model in the learning process for this topic. Corrosion is the oxidative damage of metal, for example rust on iron (Kurniawati et al., 2024). Corrosion is one of science topics. Science material has characteristics that distinguish it from other disciplines, namely it is objective because it is based on empirical facts from observations and experiments that can be verified by anyone, systematic and structured because it is arranged in a logical framework consisting of interrelated concepts, principles, laws and theories, universal because its truth applies generally without being bound by space and time, and tentative because its scientific truth is temporary and can change or be improved along with the discovery of new, stronger evidence through further investigation. Corrosion is a process of damage to metal materials. It is essentially a reaction of metal to form ions on the metal surface in direct contact with water and oxygen. The corrosion of metal objects is one of the causes of damage to infrastructure and other metal objects (Natasya et al., 2022).

Based on the experiment of Atikah et al. (2025) the characteristic of science is that it is the result of a process of discovery and not simply a collection of knowledge in the form of facts, principles, theories, or laws. Scientific knowledge is acquired through ongoing interaction between problems (questions) and the physical environment surrounding living things.

Its relevance to the theories from experiments about the implementation of Project-Based Learning (PjBL) in Mathematics Education, which has the same characteristic with corrosion, explains why PjBL works by involving ideas like building knowledge, learning from others, learning by doing, different ways of being smart, learning in real-world situations, staying interested, and figuring out solutions. PjBL seems very promising for making international math learning better (Himmi et al., 2025). In addition to metacognitive awareness, this study also measured improvements in learning outcomes. This result is in line with the research conducted previously, that assessment was obtained from the pre-test and post-test; all students' scores increased (Pohan et al., 2022).

It can be concluded that increasing students' metacognitive awareness is a logical and consistent impact of implementing the PjBL model. The structured syntax of PjBL from planning, implementation, to reflection is inherently designed to train and hone each component of metacognitive awareness (declarative, procedural, conditional, and self-regulated knowledge). Thus, PjBL is not only a model for achieving academic goals, but also a powerful pedagogical framework for developing independent, reflective learners who are aware of their own thinking processes.

Conclusion

It is conclusively demonstrated that Project-Based Learning (PjBL) is an effective instructional model for significantly fostering metacognitive awareness and improving academic achievement in corrosion topics, as evidenced by the marked improvement in both metacognitive awareness ($t=4.70$, $p<0.05$) and learning outcomes ($t=4.87$, $p<0.05$) among fourth-semester Mechanical Engineering students at UNHASY. As a practical implication, the study strongly recommends the systematic integration of PjBL into the engineering curriculum, particularly for practical courses like corrosion technique. Educators should design and implement structured project-based modules to actively develop students' higher-order thinking skills and deepen their conceptual understanding, thereby better preparing them for real-world engineering challenges.

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Author Contributions

The contribution of each author is as follows: Conceptualization, Dian Anisa Rokhmah Wati; methodology and formal analysis, Roudhoutul Aulia Rochim,; validation and supervision, Ahmad Bashri; funding acquisition, Rahma Ramadhani; software, Noer Af'idah; data curation, Retno Eka Pramitasari; .; writing—original draft preparation, Dian Anisa Rokhmah Wati; project administration, Fajar Satriya Hadi; writing—review and editing, Dian Anisa Rokhmah Wati. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

Abraham, I., & Supriyati, Y. (2022). Desain Kuasi Eksperimen Dalam Pendidikan: Literatur Review. *Jurnal Ilmiah Mandala Education*, *8*(3), 2476–2482. https://doi.org/10.58258/jime.v8i3.3800

Agusdianita, N. (2023). Model Pembelajaran PJBL Untuk Meningkatkan Hasil Belajar Mahasiswa pada Perkuliahan Pengembangan Pembelajaran Tematik. *Social, Humanities, and Educational Studies (SHES): Conference Series*, *6*(3), 160–166. https://doi.org/10.20961/shes.v6i3.82319

Aliati, M., Ramadani, N. L., & Syahira, N. H. (2025). Perbandingan Pendekatan Kualitatif dan Kuantitatif Dalam Penelitian Sosial. *Jurnal Pendidikan Indonesia :Teori, Penelitian Dan Inovasi*, *5*(4), 1–18. https://doi.org/10.59818/jpi.v5i4.1759

Anderha, R. R., & Maskar, S. (2021). Pengaruh Kemampuan Numerasi Dalam Menyelesaikan Masalah Matematika Terhadap Prestasi Belajar Mahasiswa Pendidikan Matematika. *Jurnal Ilmiah Matematika Realistik*, *2*(1), 1–10. https://doi.org/10.33365/ji-mr.v2i1.774

Andini, L., & Azizah, U. (2021). Analisis Korelasi Keterampilan Metakognitif dan Minat Belajar terhadap Hasil Belajar Siswa pada Materi Kesetimbangan Kimia. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *7*(2), 472. https://doi.org/10.33394/jk.v7i2.3327

Atikah, N., & Haryanto, T. (2025). Analisis Keterampilan Proses Sains melalui Penerapan Metode Praktikum di SMAN 6 Kerinci. *Biosfer*, *10*(1), 16. Retrieved from https://journal.unpas.ac.id/index.php/biosfer/article/view/26360

Azhari, N. S., Simangunsong, H. H., Hrp, I. A. A., Afdilani, N., & Tanjung, I. F. (2023). Penerapan Project Based Learning (PJBL) untuk Meningkatkan Hasil Belajar Siswa Kelas XII IPA 1 SMA Negeri 2 Percut Sei Tuan Pada Materi Gen. *Biodik*, *9*(1), 46–51. https://doi.org/10.22437/bio.v9i1.19187

Chaniago, Y., & Febrina Dafit. (2024). Pengaruh Model Pembelajaran Project Base Learning (PJBL) terhadap Motivasi Serta Hasil Belajar Bahasa Indonesia Siswa Kelas V Sekolah Dasar. *Didaktika: Jurnal Kependidikan*, *13*(2), 1435–1444. https://doi.org/10.58230/27454312.610

Hannah, I. H., Pratiwi, D. E., & Hastungkoro, H. N. A. (2024). Peningkatan Hasil Belajar Siswa Melalui Model Project Based Learning Pada Materi Bagian-bagian Rumah di Kelas 1 SDN Putat Jaya IV-380 Surabaya. *Journal of Science and Education Research*, *3*(2), 24–29. https://doi.org/10.62759/jser.v3i2.126

Harrison, G. M., & Vallin, L. M. (2018). Evaluating the metacognitive awareness inventory using empirical factor-structure evidence. *Metacognition and Learning*, *13*(1), 15–38. https://doi.org/10.1007/s11409-017-9176-z

Himmi, N., Armanto, D., & Amry, Z. (2025). Implementation of Project Based Learning (PjBL) in Mathematics Education : A Systematic Analysis of International Practices and Theoretical Foundations. *Science Insights Education Frontiers*, *26*(2), 4306–4321. https://doi.org/10.15354/sief.25.or699

Hindun, I., Nurwidodo, N., & Wicaksono, A. G. C. (2020). Metacognitive awareness components of high-academic ability students in biology hybrid learning: Profile and correlation. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 31–38. https://doi.org/10.22219/jpbi.v6i1.11097

Kurniawati, I. L., & Wati, D. A. R. (2024). *Korosi: Teori dan Pencegahannya*. Gadjah Mada University Press.

Lenaini, I. (2021). Teknik Pengambilan Sampel Purposive Dan Snowball Sampling. *HISTORIS: Jurnal Kajian, Penelitian & Pengembangan Pendidikan Sejarah*, *6*(1), 33–39. Retrieved from http://journal.ummat.ac.id/index.php/historis

Louca, E. P. (2019). Do children know what they know? Metacognitive awareness in preschool children. *New Ideas in Psychology*, *54*(July), 56–62. https://doi.org/10.1016/j.newideapsych.2019.01.005

Lukitasari, M., Hasan, R., Sukri, A., & Handhika, J. (2021). Developing student's metacognitive ability in science through project-based learning with e-portfolio. *International Journal of Evaluation and Research in Education*, *10*(3), 948–955. https://doi.org/10.11591/IJERE.V10I3.21370

Mulyani, D. F., & Arif, S. (2021). Implementation of Project Based Learning (Pjbl) Based on Science, Technology, Engineering and Mathematics (Stem) To Improve Metacognitive Thinking Ability. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *2*(1), 117–129. https://doi.org/10.21154/insecta.v2i1.2931

Natasya, T., Khairafah, M. E., Sari, M., Sembiring, B., & Nazrifah, L. (2022). Corrosion Factors on Nail. *Indonesian Journal of Chemical Science and Technology*, *5*(1), 47–50. https://doi.org/10.24114/ijcst.v5i1.33159

Nurhadiyati, A., Rusdinal, R., & Fitria, Y. (2020). Pengaruh Model Project Based Learning (PJBL) terhadap Hasil Belajar Siswa di Sekolah Dasar. *Jurnal Basicedu*, *5*(1), 327–333. https://doi.org/10.31004/basicedu.v5i1.684

Nyimbili, F., & Nyimbili, L. (2024). Types of Purposive Sampling Techniques with Their Examples and Application in Qualitative Research Studies. *British Journal of Multidisciplinary and Advanced Studies*, *5*(1), 90–99. https://doi.org/10.37745/bjmas.2022.0419

Ompusunggu, E., Simatupang, L., Zubir, M., Syahputra, R. A., Selly, R., Aprilyani, J., & Sitompul, N. (2020). Analysis of Corrosion Rate With Addition of Pumps in Commercial Steel in Sea Water Media. *Indonesian Journal of Chemical Science and Technology*, *3*(1), 31–34. https://doi.org/10.24114/ijcst.v3i1.18339

Pohan, L. A., & Maulina, J. (2022). Blended Learning Integrated with Project-Based Learning : Its Effect on Learning Outcomes , Perception , and Self-Regulated Learning. *Jurnal Pendidikan Kimia Indonesia*, *6*(2), 97–106. https://doi.org/10.23887/jpki.v6i2.48213

Ramadhanti, D., & Yanda, D. P. (2021). Students' metacognitive awareness and its impact on writing skill. *International Journal of Language Education*, *5*(3), 193–206. https://doi.org/10.26858/ijole.v5i3.18978

Setiawan, P., & Arip, A. G. (2023). Application of the Project Based Learning (PjBL) Model through Making Tempe to Improve Student Learning Outcomes and Creativity. *Influence: International Journal of Science Review*, *5*(2), 239–249. https://doi.org/10.54783/influencejournal.v5i2.153

Singh, A., & Diefes-Dux, H. A. (2023). Pairing Self-Evaluation Activities with Self-Reflection to Engage Students Deeply in Multiple Metacognition Strategies. *ASEE Annual Conference and Exposition, Conference Proceedings*.

https://doi.org/10.18260/1-2--43847

Siqueira, M. A. M., Gonçalves, J. P., Mendonça, V. S., Kobayasi, R., Arantes-Costa, F. M., Tempski, P. Z., & Martins, M. de A. (2020). Relationship between metacognitive awareness and motivation to learn in medical students. *BMC Medical Education*, *20*(1), 1–10. https://doi.org/10.1186/s12909-020-02318-8

Sirotová, M., Michvocíková, V., & Rubacha, K. M. (2021). Quasi-experiment in the educational reality. *Journal of Education Culture and Society*, *12*(1), 189–201. https://doi.org/10.15503/jecs2021.1.189.201

Syahmani, Saadi, P., Clarita, D., & Sholahuddin, A. (2021). Guided inquiry assisted by metacognitive questions to improve metacognitive skills and students conceptual understanding of chemistry. *Journal of Physics: Conference Series*, *1760*(1). https://doi.org/10.1088/1742-6596/1760/1/012023

Wulandari, M. A., Senen, A., Wardani, D. S., & Ruqoyyah, S. (2025). Transforming Education Through Project-Based Learning (PjBL): Enhancing Students ' Learning Outcomes and Critical Thinking. *Jurnal Profesi Pendidikan*, *4*(1), 200–215. https://doi.org/10.22460/jp p.v4i1.27655

Zhang, L., Li, S., Zhao, Q., Ferrero, M., Vadillo, M. A., León, S. P., Krajcik, Joseph S. and Blumenfeld, P. C., Francisco, A. R. L., & Flavell, J. H. (2021). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, *34*(4), 1689–1699. https://doi.org/10.1371/journal.pone.0249627