



The Influence of the Problem Based Learning Model Based on the STEM Approach on Students' Higher Order Thinking Skills (HOTS) in Acid Base Material

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Abstract: The Influence of the Problem Based Learning Model Based on the STEM Approach on Students' Higher Order Thinking Skills (HOTS) in Acid-Base Material.

This study aims to investigate the influence of the problem based learning model based on the stem approach on students' higher order thinking skills (hots) in acid-base material. The research employed a quasi-experimental method with a pretest-posttest control group design. The population consisted of five grade XI classes at SMA Negeri 17 Medan. The sample was selected through random sampling, resulting in two classes: class XI E as the experimental group and class XI D as the control group. Data were analyzed using hypothesis testing with a one-tailed t-test and N-gain analysis. Based on the analysis, the results of the hypothesis testing showed that $t_{count} > t_{table}$ ($4.736 > 1.997$). Furthermore, the N-gain score for the experimental group (0.75) fell into the high category, while the control group (0.66) was in the moderate category. Consequently, it can be concluded that the implementation of the STEM based Problem-Based Learning model has a significant effect on enhancing students' higher-order thinking skills in acid-base concepts.

Keywords: Acid-base, Higher-order thinking skills (HOTS), Problem-Based Learning (PBL), STEM.

Abstrak: Pengaruh Model Problem Based Learning Berbasis Pendekatan STEM Terhadap Kemampuan Berpikir Tingkat Tinggi (HOTS) Siswa Pada Materi Asam Basa.

Penelitian ini bertujuan untuk mengetahui pengaruh model Problem Based Learning berbasis pendekatan STEM terhadap kemampuan berpikir tingkat tinggi (HOTS) siswa serta peningkatannya pada materi asam basa. Penelitian ini menggunakan metode quasi eksperimen dengan desain pretest-posttest control group. Populasi penelitian ini adalah siswa kelas XI SMA Negeri 17 Medan. Sampel dipilih secara random sampling yang terdiri dari 2 kelas yaitu kelas XI E sebagai eksperimen dan XI D sebagai kelas kontrol. Data dianalisis menggunakan uji hipotesis dengan uji t satu pihak dan N-gain. Berdasarkan data hasil penelitian setelah dianalisis hasil uji hipotesis menunjukkan bahwa nilai $t_{hitung} > t_{tabel}$ yaitu $4,736 > 1,997$. Selain itu, nilai n-gain kelas eksperimen (0,75) berada pada kategori tinggi sedangkan kelas kontrol (0,66) berada pada kategori sedang. Dengan demikian, dapat disimpulkan bahwa penerapan model Problem Based Learning berbasis STEM berpengaruh signifikan dalam meningkatkan kemampuan berpikir tingkat tinggi siswa pada materi asam basa.

Kata kunci: Asam basa, kemampuan berpikir tingkat tinggi (HOTS), Problem Based Learning, STEM.



▪ INTRODUCTION

Education is an essential element for a nation's progress, where in this era of globalization, 21st-century learning facilitates the integration of rapidly evolving technology (Rosnaeni, 2021). 21st-century education emphasizes the mastery of four key skills known as the 4Cs: Creativity, Communication, Critical Thinking and Problem Solving, and Collaboration (Mahmudah et al., 2024). Consequently, the development of learning models adapted to the 21st century is vital to shift the focus from teacher-centered to student-centered learning (Handayani & Wulandari, 2021). In this context, teachers serve as facilitators who assist in linking students' prior knowledge with new information (Putriani & Hudaiah, 2021).

However, reality in the field reveals significant challenges, one of which is the low level of students' Higher-Order Thinking Skills (HOTS) caused by the use of conventional lecture methods that limit critical thinking development. This issue is particularly evident in chemistry topics such as acid-base, which Ekawisudawati et al. (2021) describe as complex due to its relation to ionic equilibrium, salt solution pH, and titration. Furthermore, Atika & Latisma (2022) mention that students often face difficulties in analyzing solution properties, determining pH ranges, and calculating pH or pOH. This deficiency in HOTS is influenced by motivation, environment, and the instructional models employed (Anggriani & Atmojo, 2022).

Preliminary observations and interviews conducted with the chemistry teacher at SMA Negeri 17 Medan revealed that chemistry learning was still predominantly conducted through lectures and simple classroom discussions. As a result, students tended to be passive during learning activities and experienced difficulties in analyzing acid–base concepts, determining pH values, interpreting acid–base indicators, and solving contextual chemistry problems. In addition, classroom assessments were still dominated by lower-order cognitive (LOTS) questions, causing students to become accustomed to memorizing concepts rather than analyzing, evaluating, and solving problems critically. These findings indicate that students' Higher-Order Thinking Skills have not been optimally developed.

To address these challenges, an appropriate learning model is required to connect academic material with real-world situations. One of the most effective models for enhancing higher-order thinking skills is Problem-Based Learning (PBL). PBL is a model that emphasizes problem-solving as the core of the learning process (Mangelep et al., 2023). Through this model, students are challenged to find solutions to real-world problems collaboratively in groups (Kristiana & Radia, 2021). The implementation of PBL has been proven to stimulate students' higher-order thinking through problem-oriented situations (Rampi et al., 2021).

In addition to the choice of model, integrating the Science, Technology, Engineering, and Mathematics (STEM) approach serves as a crucial innovation, as it is an interdisciplinary approach that unifies these four fields (Smith et al., 2022). The STEM approach can strengthen problem-based teaching and learning by focusing on concrete problem-solving (Abas et al., 2024). This aligns with findings by Suciana & Sausan (2023), which indicate that PBL-STEM has a significant effect on student achievement. Similarly, previous research by Ulum et al. (2025) states that there is a significant influence of the STEM based PBL model on HOTS, based on hypothesis testing using an independent sample t-test with a Sig. value of $0.000 < 0.05$, which also yields a positive impact on improving the higher-order thinking skills of high school students (Davidi et al., 2021).

Several previous studies have reported that the integration of STEM into the Problem-Based Learning model significantly improves students' learning outcomes and Higher-Order Thinking Skills. However, most previous studies were conducted in different educational contexts and learning materials. Research specifically investigating the implementation of the STEM based Problem-Based Learning model to improve students' Higher-Order Thinking Skills in acid–base learning.

Accordingly, this study aims to determine the effect of the STEM based Problem-Based Learning model on students' Higher-Order Thinking Skills and to determine the magnitude of students' HOTS improvement in acid–base learning compared with Direct Instruction.

▪ METHOD

This study employed a quantitative research approach using a quasi-experimental method with a pretest–posttest control group design. According to Sugiyono (2021), a quasi-experimental design is used to determine the effect of a particular treatment on another variable when the researcher cannot fully control all external variables influencing the experiment. In this study, two groups were involved: an experimental class that received instruction using the STEM based Problem-Based Learning (PBL) model and a control class that was taught using the Direct Instruction model. Before the learning treatment, both groups were administered a pre-test to determine their initial Higher-Order Thinking Skills (HOTS). After the learning intervention, a post-test was administered to evaluate the improvement in students' HOTS.

Group	Pretest	Treatment	Posttest
Experimental	Q ₁	STEM based Problem Based Learning	Q ₂
Control	Q ₁	Direct Instruction	Q ₂

The research was conducted at SMA Negeri 17 Medan during the second semester of the 2025/2026 academic year. The population consisted of all Grade XI students. The research sample was selected using simple random sampling through a class lottery technique, as recommended by Sugiyono (2019), whereby every class had an equal opportunity to be selected as the research sample. Based on the lottery results, Class XI-E, consisting of 33 students, was selected as the experimental class, while Class XI-D, consisting of 33 students, served as the control class.

The research instrument was a Higher-Order Thinking Skills (HOTS) test in the form of multiple-choice questions developed based on the revised Bloom's Taxonomy, covering the cognitive domains of Analyzing (C4), Evaluating (C5), and Creating (C6). Prior to implementation, the instrument underwent content validation by chemistry education experts and was empirically tested on Grade XII students of SMA Negeri 17 Medan. Initially, the instrument consisted of 40 multiple-choice questions. The empirical validity test indicated that 22 items met the validity criteria, whereas 18 items were declared invalid. From the 22 valid items, 20 questions were selected for the pre-test and post-test because they best represented the learning indicators and fulfilled the psychometric requirements. The reliability of the test instrument was assessed using the Kuder–Richardson Formula 20 (KR-20) (Silitonga, 2014), yielding a reliability coefficient of 0.8298, which indicates high instrument reliability. Furthermore, the item analysis showed that the instrument consisted of 3 easy items, 14 moderate items, and 5

difficult items, while the discrimination index classified 11 items as good, 10 items as satisfactory, and 1 item as poor.

The experimental class was taught using the STEM based Problem-Based Learning model through five learning stages: (1) orienting students to contextual problems, (2) organizing students into collaborative learning groups, (3) guiding individual and group investigations integrated with Science, Technology, Engineering, and Mathematics (STEM), (4) developing and presenting problem-solving results, and (5) analyzing and evaluating the problem-solving process. Meanwhile, the control class received instruction using the Direct Instruction model. The learning treatment was implemented for 3 meetings, excluding the pre-test and post-test sessions.

The collected data were analyzed using Microsoft Excel and IBM SPSS Statistics version 23. Before testing the research hypothesis, prerequisite analyses were conducted, including the Shapiro–Wilk normality test and Levene's homogeneity test at a significance level of 0.05. After the data met the assumptions of normality and homogeneity, the hypothesis was tested using the Independent Sample *t*-test. In addition, the effectiveness of the learning model in improving students' Higher-Order Thinking Skills was analyzed using the normalized gain (N-Gain). According to Sugiyono (2019), statistical analysis is conducted to test the proposed hypothesis and determine whether the observed differences between groups are statistically significant.

▪ RESULT AND DISCUSSION

Result

Students' higher-order thinking skills data were obtained through a pre-test and a post-test in both the experimental and control classes to provide an overview of the conditions before and after the treatment. The pre-test results were used to determine the students' initial abilities in both classes, while the post-test results indicated the students' abilities after the learning process was implemented. Subsequently, these data were further analyzed. The pre-test and post-test data for students' higher-order thinking skills in the experimental and control classes are presented in Table 1 below.

Table 1. Mean Pre-test and Post-test Scores

Class	Mean Pretest	Mean Posttest
Experimental	34.54	83.93
Control	35.15	76.36

Based on the table, it is observed that the mean pre-test score for the experimental class was 34.54, which increased significantly to 83.93 in the post-test. Meanwhile, in the control class, the mean pre-test score was 35.15, with a post-test score of 76.36. Drawing from Table 1, the comparison of the mean pre-test and post-test scores between the experimental and control classes is illustrated in the chart in Figure 1 below.

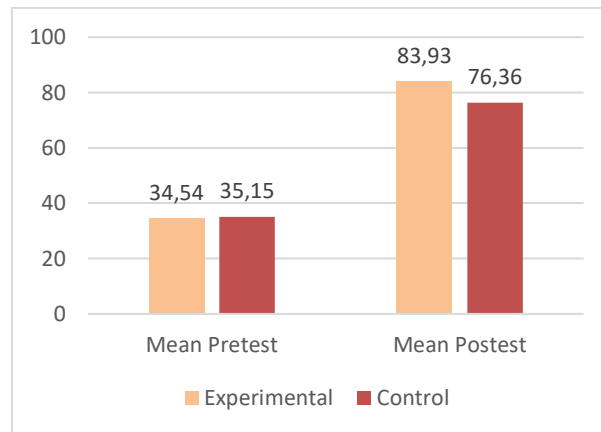


Figure 1. Mean Pre-test and Post-test Scores

The data on students' higher-order thinking skills were statistically analyzed using a one-tailed t-test. Prior to the hypothesis testing, prerequisite tests, including normality and homogeneity tests, were conducted. Once all prerequisites were met, the analysis proceeded to hypothesis testing to determine the presence of a significant effect on students' higher-order thinking skills..

Normality Test

The normality test was conducted to determine whether the data are normally distributed. This test was performed using the Shapiro-Wilk method via SPSS 23. Data are considered normally distributed if the significance value (Sig.) is greater than 0.05. The results indicated that the data for both the control and experimental classes follow a normal distribution. The normality test results for the experimental and control classes are presented in the following table.

Table 1. Normality Test of the Experimental Class

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest Experimental	.137	33	.119	.953	33	.163
Posttest Experimental	.157	33	.038	.941	33	.074

The table above shows that in the experimental class, the significance values (Sig.) for the pre-test and post-test data are 0.163 and 0.074, respectively. Both values are greater than the significance level of 0.05 (α). Therefore, it can be inferred that the data in the experimental class are normally distributed.

Table 2. Normality Test of the Control Class

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest Control	.160	33	.031	.942	33	.079
Posttest Control	.176	33	.011	.949	33	.122

Based on the normality tests conducted on the control class, the significance values (Sig.) obtained were 0.079 for the pre-test data and 0.122 for the post-test data.

These results indicate that the data in the control class are normally distributed. Consequently, it can be concluded that the research can proceed with parametric statistical analysis.

Homogenitas Test

The homogeneity test was conducted to determine whether the data distribution possesses a homogeneous variance. This test was performed using the Levene's statistic test assisted by SPSS 23 software at a significance level of 0.05. The results of the homogeneity test are presented in Table 4 below.

Table 4. Homogeneity Test of Pre-test and Post-test Scores

Data	Sig	α	Information
Pretest	0.142	0.05	Homogeneous
Posttest	0.961	0.05	Homogeneous

The table above indicates that the significance value (Sig.) for the pre-test data is 0.142. Since the Sig. value for the pre-test is greater than 0.05 (the significance level), it can be inferred that the pre-test data for both the control and experimental classes are homogeneous. Meanwhile, the post-test data yielded a Sig. value of 0.961. Because the Sig. value for the post-test is greater than 0.05, it is understood that the post-test data for the control and experimental classes are also homogeneous. Consequently, it can be concluded that the data from both groups, the experimental and control classes, possess equal variance (homogeneous).

Hypothesis Testing

The hypothesis testing in this study was conducted using the Independent Sample t-Test with a significance level of 0.05. The decision-making process in this test is determined by comparing the obtained significance values. The hypothesis is accepted if the t_{count} value is greater than the t_{table} ($t_{\text{count}} > t_{\text{table}}$), thus H_0 is rejected and H_a is accepted).

When using SPSS for data processing, the significance value (p-value) can be evaluated directly without comparing t_{count} to t_{table} . If the significance value is less than 0,05 ($p < 0,05$) the result is considered significant, meaning that a significant effect exists, and vice versa. In this study, the experimental class was taught using the Problem-Based Learning model integrated with a STEM approach, while the control class was taught using the Direct Instruction model. The results of the hypothesis testing are presented in Table 5.

Table 5. Hypothesis Testing

Class	Mean	t count	t table	Sig. (2-tailed)	Information
Experimental	83.93	4.736	1.997	0.000	H_0 rejected, H_a accepted
Control	76.36				

The Independent Sample t-test revealed that the calculated t-value (4.736) was greater than the critical t-value (1.997). In addition, the significance value obtained from SPSS was 0.000, which was lower than the significance level of 0.05. These findings indicate that H_a was accepted, confirming that the implementation of the STEM based

Problem-Based Learning model had a statistically significant effect on students' Higher-Order Thinking Skills in acid–base learning.

N-Gain Test

The N-gain test was conducted to determine the extent of the improvement in students' higher-order thinking skills. This test was performed by comparing the normalized difference between the pre-test and post-test scores of both classes. The results of the N-Gain improvement data are presented in Table 6 below.

Table 6. Improvement N-Gain

Class	Mean Pretest	Mean Posttest	N-Gain	Category
Experimental	34.54	83.93	0.75	High
Control	35.15	76.36	0.64	Moderate

Based on the results of the N-Gain analysis, both classes demonstrated a difference in gain scores after receiving different treatments. The experimental class achieved an N-Gain score of 0.75, which is classified in the high category, while the control class achieved an N-Gain score of 0.64, falling into the moderate category.

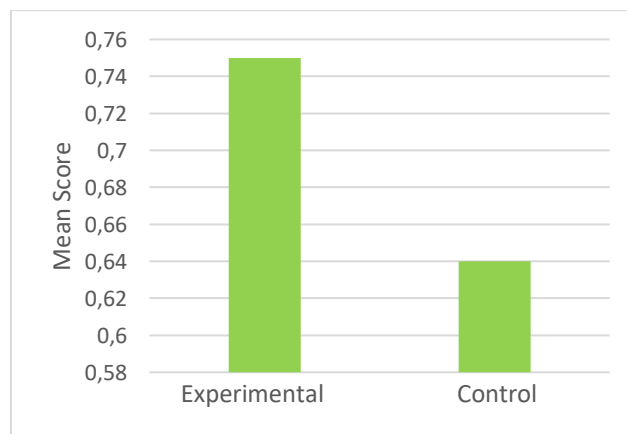


Figure 2. Improvement N-Gain

Discussion

The findings of this study indicate that the implementation of the STEM based Problem-Based Learning (PBL) model significantly improved students' Higher-Order Thinking Skills (HOTS) in acid–base learning. This conclusion is supported by the Independent Sample *t*-test results, which showed that the calculated *t*-value (4.736) was greater than the critical *t*-value (1.997), with a significance value of 0.000 ($p < 0.05$). Furthermore, the N-Gain analysis demonstrated that the experimental class achieved a high improvement (0.75), whereas the control class achieved only a moderate improvement (0.64). These findings indicate that students who learned through the STEM based Problem-Based Learning model experienced greater improvement in Higher-Order Thinking Skills than those who received Direct Instruction.

Theoretically, the improvement in students' Higher-Order Thinking Skills can be explained by the characteristics of the Problem-Based Learning model itself. According to constructivist learning theory proposed by Piaget and Vygotsky, knowledge is not transmitted directly from the teacher to students but is actively constructed through

interaction with the environment, previous experiences, and social collaboration. The STEM based Problem-Based Learning model provides opportunities for students to identify problems, formulate hypotheses, investigate scientific evidence, discuss alternative solutions, and reflect on their learning experiences. These activities require students to analyze information (C4), evaluate evidence (C5), and create appropriate solutions (C6), which correspond to the cognitive dimensions of Higher-Order Thinking Skills. Consequently, students actively construct conceptual understanding instead of merely memorizing scientific facts.

The findings of this study are also consistent with the principles of twenty-first-century learning, which emphasize the development of the 4C competencies, namely Critical Thinking, Creativity, Collaboration, and Communication. During the implementation of the STEM based Problem-Based Learning model, students worked collaboratively in small groups to investigate contextual acid–base problems, communicate scientific ideas, evaluate alternative solutions, and present the results of their investigations. These learning experiences not only improved students' conceptual understanding but also fostered essential competencies required in twenty-first-century education. Therefore, the implementation of STEM based Problem-Based Learning is in line with current educational goals that encourage students to become active, critical, collaborative, and creative learners.

The findings of this study are consistent with previous empirical studies regarding the effectiveness of Problem-Based Learning and STEM integration in improving students' Higher-Order Thinking Skills. The results of this study are reinforced by the research of Harahap and Simorangkir (2024) and Situmeang and Simorangkir (2023), which demonstrated that the implementation of Problem-Based Learning (PBL) significantly improved students' learning outcomes, as indicated by calculated t -values exceeding the critical t -values. These studies confirm that PBL is effective because it promotes student-centered learning, actively engages students in problem-solving, and facilitates deeper conceptual understanding compared with conventional instruction.

Furthermore, the present findings are also in agreement with the study conducted by Chamidah and Suhartono (2023), which reported that the STEM based PBL model significantly improved students' Higher-Order Thinking Skills, with a significance value of 0.002 ($p < 0.05$). Similarly, Ulum et al. (2025) found a significant effect of the STEM based PBL model on students' HOTS, as evidenced by an Independent Sample t -test result of $\text{Sig.} = 0.000 < 0.05$. Likewise, Davidi et al. (2021) reported that integrating STEM into learning activities positively influenced senior high school students' Higher-Order Thinking Skills. The consistency between the present findings and previous studies strengthens the evidence that integrating STEM into Problem-Based Learning provides meaningful learning experiences that effectively enhance students' Higher-Order Thinking Skills.

Another factor contributing to the improvement in HOTS was the integration of the Science, Technology, Engineering, and Mathematics (STEM) approach into the learning process. Rather than learning acid–base concepts as isolated theories, students were encouraged to relate chemistry concepts to authentic real-life situations through interdisciplinary problem-solving activities. The integration of science concepts with technological applications, engineering design, and mathematical reasoning enabled students to understand acid–base concepts more meaningfully. Students not only learned how to calculate pH or identify acid–base properties but also understood how these concepts can be applied to solve problems encountered in everyday life. Such meaningful

learning experiences encourage deeper conceptual understanding and promote higher-order thinking.

The superiority of the STEM based Problem-Based Learning model over Direct Instruction can also be explained by differences in students' learning experiences. In the experimental class, students actively participated throughout the learning process by identifying problems, conducting investigations, discussing findings, and presenting solutions. These activities required students to think critically, evaluate information, and justify scientific arguments. In contrast, students in the control class mainly received teacher explanations followed by guided exercises. Although this approach improved students' conceptual knowledge, opportunities to independently construct knowledge, investigate problems, and develop creative solutions were relatively limited. Consequently, the improvement in Higher-Order Thinking Skills observed in the control class was lower than that in the experimental class.

The findings of this study support previous empirical studies reporting that integrating STEM into Problem-Based Learning effectively enhances students' Higher-Order Thinking Skills, critical thinking, and problem-solving abilities. The consistency between the present findings and previous studies strengthens the evidence that interdisciplinary learning through authentic problems creates more meaningful learning experiences than conventional teacher-centered instruction.

Besides its effectiveness, the implementation of the STEM based Problem-Based Learning model also demonstrated several educational advantages in acid–base learning. The model encouraged students to participate actively in classroom discussions, increased collaboration among group members, improved scientific communication skills, and motivated students to relate chemistry concepts to everyday phenomena. Students became more confident in expressing ideas, defending arguments based on scientific evidence, and solving contextual chemistry problems. These learning experiences support the development of Higher-Order Thinking Skills while simultaneously promoting other essential twenty-first-century competencies.

However, several challenges were encountered during the implementation of the STEM based Problem-Based Learning model. The learning process required a longer instructional time than conventional teaching because students needed sufficient time to identify problems, conduct investigations, discuss findings, and present their solutions. In addition, successful implementation depended greatly on the teacher's ability to manage collaborative learning activities, facilitate group discussions, and integrate STEM components effectively. Some students also required additional guidance during the early stages of learning because they were not yet accustomed to student-centered instruction and independent problem-solving activities. Despite these challenges, the educational benefits obtained from implementing the STEM based Problem-Based Learning model outweighed its limitations.

Overall, the findings of this study demonstrate that the STEM based Problem-Based Learning model is more effective than Direct Instruction in improving students' Higher-Order Thinking Skills in acid–base learning. By integrating authentic problem-solving with Science, Technology, Engineering, and Mathematics, the model provides meaningful learning experiences that enable students to develop conceptual understanding, critical thinking, creativity, collaboration, communication, and scientific reasoning simultaneously. Therefore, the STEM based Problem-Based Learning model can be recommended as an effective instructional strategy for promoting Higher-Order Thinking Skills in chemistry education.

The results of this study are reinforced by the research of Harahap & Simorangkir (2024) and Situmeang & Simorangkir (2023), which demonstrates that the implementation of Problem-Based Learning (PBL) significantly influences the improvement of student learning outcomes. This is further substantiated by t_{count} values that exceed the t_{table} . Both studies confirm that PBL is effective in enhancing learning outcomes because it is student-centered, requires active engagement in problem-solving, and encourages a deeper conceptual understanding compared to conventional instruction.

Furthermore, these findings align with the study by Chamidah & Suhartono (2023), which states that the application of the STEM based PBL model significantly impacts students' higher-order thinking skills, with a significance value of 0.002 ($p < 0.05$). Similarly, a previous study conducted by Ulum et al. (2025) reported a significant effect of the STEM based PBL model on high-order thinking skills, based on an independent sample t-test result of Sig. 0.000 < 0.05. These results are also consistent with research by Davidi et al. (2021), which indicates that STEM assisted instructional steps have a positive effect on enhancing the higher-order thinking skills of senior high school students.

▪ CONCLUSION

Based on the results of data analysis and hypothesis testing, it can be concluded that the implementation of the Problem-Based Learning (PBL) model integrated with the STEM approach significantly affects the improvement of students' Higher-Order Thinking Skills (HOTS) in acid-base material. This is evidenced by the hypothesis test results, which show that the t_{count} value exceeds the t_{table} value ($4.736 > 1.997$) thus, the alternative hypothesis (H_a) is accepted and the null hypothesis (H_0) is rejected. Furthermore, the effectiveness of this model is reflected in the experimental class's N-Gain score of 0.75, categorized as high, which surpassed the control class's N-Gain score of 0.64, categorized as moderate. Consequently, the integration of the STEM approach into the Problem-Based Learning model is proven to be more optimal in facilitating the development of students' higher-order thinking skills compared to conventional methods.

▪ REFERENCES

- Abas, S., Alirahman, A. D., & Maburur, H. (2024). Humanizing Stem Based Learning (Science, Technology, Engineering, And Mathematics) For The Transformation Of Islamic Education In The 21st Century. *Educan: Jurnal Pendidikan Islam*, 8(1), 98–120. <https://doi.org/10.21111/educan.v8i1.11429>
- Anggriani, M. D., & Atmojo, S. E. (2022). The Impact Of Problem-Based Learning Model Assisted By Mentimeter Media In Science Learning On Students' Critical Thinking And Collaboration Skills. *International Journal Of Elementary Education*, 6(2), 350–359.
- Atika, M. D., & Latisma, L. (2022). Deskripsi Kesulitan Belajar Kimia Siswa Pada Materi Asam Basa Kelas XI IPA Di SMA Negeri 7 Padang. *Entalpi Pendidikan Kimia*, 3(3), 18–26.
- Chamidah, A., & Suhartono. (2023). Problem-Based Learning And Stem On The Hots Ability Of High School ' S Students In Surabaya. *Matematika Dan Pembelajaran*, 11(1), 1–9.
- Davidi, E. I. N., Sennen, E., & Supardi, K. (2021). Integrasi Pendekatan Stem (Science , Technology , Enggeenering And Mathematic) Untuk Peningkatan Keterampilan Berpikir Kritis Siswa Sekolah Dasar. *Scholaria: Jurnal Pendidikan Dan*

- Kebudayaan*, 11(1), 11–22.
- Ekawisudawati, E., Wijaya, M., & Danial, M. (2021). Analisis Miskonsepsi Peserta Didik Pada Materi Asam Basa Menggunakan Instrumen Three-Tier Diagnostic Test. *Chemistry Education Review (CER)*, 5(1), 62–72. <https://doi.org/10.26858/cer.v5i1.13315>
- Handayani, R., & Wulandari, D. (2021). Modern Assessment Dalam Menyongsong Pembelajaran Abad 21 Dan Hambatan Di Negara Berkembang. *Jurnal Pendidikan Edutama*, 8(1), 13–23. <https://doi.org/10.30734/jpe.v8i1.1363>
- Harahap, S. W., & Simorangkir, M. (2024). Differences In Learning Outcomes And Critical Thinking Ability Of Students Taught Using Learning Video Media And Powerpoint With Problem Based Learning Model On Reaction Rate Material. *Jurnal Pendidikan Dan Pembelajaran Kimia*, 14(4), 36–45. <https://doi.org/10.23960/Jppk.V13.I1.2024.04>
- Kristiana, T. F., & Radia, E. H. (2021). Meta Analisis Penerapan Model Problem Based Learning Dalam Meningkatkan Hasil Belajar IPA Siswa Sekolah Dasar. *Jurnal Basicedu*, 5(2), 818–826.
- Mahmudah, F. N., Setyaningrum, W., & Faisal, M. (2024). Tren Penelitian Integrasi ICT Dalam Pembelajaran Matematika Untuk Meningkatkan Keterampilan Abad 21. *Aksioma: Jurnal Program Studi Pendidikan Matematika*, 13(3), 895–906. <https://doi.org/10.24127/ajpm.v13i3.8635>
- Mangelep, dkk. (2023). (Sesuai referensi pada teks Anda mengenai penggunaan metode ilmiah dalam PBL).
- Putriani, J. D., & Hudaidah, H. (2021). Penerapan Pendidikan Indonesia Di Era Revolusi Industri 4.0. *Edukatif: Jurnal Ilmu Pendidikan*, 3(3), 830–838. <https://doi.org/10.31004/edukatif.v3i3.407>
- Rampi, O., Pongoh, E., & Caroles, J. (2021). Penerapan Model Pembelajaran Problem Based Learning (PBL) Pada Materi Asam Basa Siswa Kelas XI IPA Di SMA Negeri 1 Tenga. *Oxygenius Journal Of Chemistry Education*, 3(2), 102–108. <https://doi.org/10.37033/ojce.v3i2.304>
- Rosnaeni. (2021). Karakteristik Dan Asesmen Abad 21. *Jurnal Basicedu*, 5(5), 4334–4339.
- Silitonga, P. M. (2014). *Statistik Teori Dan Aplikasi Dalam Penelitian*. Medan : Fmipa Universitas Negeri Medan.
- Situmeang, J., & Simorangkir, M. (2023). The Effect Of Virtual Lab Assisted Pbl Model On Student Motivation And Learning Outcomes. *Jurnal Pendidikan Dan Pembelajaran Kimia*, 12(2), 255–262.
- Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta.
- Sugiyono. (2021). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif Dan R&D)*. Bandung: Alfabeta.
- Smith, K., Maynard, N., Berry, A., et al. (2022). Principles Of Problem-Based Learning (PBL) In Stem Education: Using Expert Wisdom And Research To Frame Educational Practice. *Education Sciences*, 12(10), 1–20.
- Ulum, A. W. I. T., Astutik, S., Nurdin, E. A., Yushardi, & Kurnianto, F. A. (2025). Pengaruh Model Pembelajaran Problem Based Learning (Pbl) Berbasis Stem Terhadap Kemampuan Berpikir Tingkat Tinggi Dan Hasil Belajar Geografi Siswa Sma. *Edu Geography*, 13(2), 103–111. <https://doi.org/10.15294/Edugeo.V11i2.69710>