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The Impact of Problem-Based Learning on Students' Problem-Solving Skills and Learning Motivation: A Perspective on Learning Styles

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Abstract: Problem-solving ability and learning motivation are essential in chemistry learning, yet often overlooked in conventional instruction. This study investigates the effects of problem-based learning (PBL) versus discovery learning on students' problem-solving ability and motivation, while also examining the influence of learning styles. Using a quasi-experimental pretest-posttest control group design, XI MIPA students at SMA Negeri 9 Bengkulu City were assigned to either a PBL or discovery learning group. Data were collected through tests, questionnaires, and learning style inventories, and analyzed using MANOVA. Results indicated no significant difference between the two models in improving problem-solving ability or motivation. However, learning styles significantly affected both outcomes, with visual, auditory, and kinesthetic learners performing differently. PBL contributed modestly to both variables (2.4% for problem-solving, 0.4% for motivation), and no interaction effect with learning styles was found. These findings highlight the need to align teaching strategies with students' learning styles to support more effective learning. The study offers practical implications for fostering adaptive instruction in chemistry classrooms and enhancing scientific literacy.

Keywords: Learning motivation; Learning style; Problem-based learning; Problem solving ability; Salt hydrolysis.

Introduction

Education plays a strategic role in developing high-quality and competitive human resources. As stated in the Preamble to the 1945 Constitution and Law No. 20 of 2003 on the National Education System, the goal of education is to develop students' potential so that they become individuals who are faithful, pious, morally upright, knowledgeable, creative, and responsible. To achieve this goal, the education system must be supported by a curriculum that is adaptive and relevant to the developments of the times (Uce, 2016). The curriculum plays a crucial role in ensuring that the learning process runs optimally and aligns with students' needs. However, in practice, periodic curriculum changes in Indonesia often pose challenges in their implementation (Santika et al., 2022). One of the significant changes in Indonesia's education system was the implementation of the 2013 Curriculum, which aimed to shift the learning approach from being teacher-centered to student-centered learning (Jayadi et al., 2020). This approach is particularly essential in science subjects such as chemistry, which require deep understanding and critical thinking skills to solve scientific problems.

Chemistry is a complex subject as it involves many abstract concepts, chemical reactions, and mathematical calculations, which often become obstacles for students in understanding the material (Ristiyani & Bahriah, 2016). One of the chemistry topics that is relatively

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difficult to understand is salt hydrolysis, which requires an in-depth understanding of ionization concepts, acid-base reactions, and pH calculations of salt solutions. According to research conducted by Maratusholihah et al., (2017) students' difficulties in understanding salt hydrolysis arise from the interconnectedness of various fundamental concepts that must be mastered simultaneously. Another study by Janah et al., (2018) also found that many students struggle to determine the characteristics of salts that can undergo hydrolysis in water, analyze the properties of salts based on ionization reactions, and correctly calculate the pH of salt solutions. These difficulties may be attributed to conventional learning approaches that do not actively engage students in understanding the concepts being taught.

In many schools, the learning process is still dominated by teacher-centered learning methods, where students tend to be passive recipients of information (Nurlina et al., 2015). Furthermore, commonly implemented learning methods, such as discovery learning, also face various challenges in their application. Rahmayani et al., (2019) and Takuya et al., (2019) revealed that in discovery learning, students often struggle because they must explore concepts independently without adequate guidance, making it difficult for them to develop hypotheses and verify concepts effectively. Therefore, a more systematic learning model is needed to help students gain a deeper understanding of concepts and enhance their critical thinking skills. One approach that can be used is problem-based learning, which has been widely studied as an effective method for improving students' understanding and problem-solving skills.

Problem-based learning is a learning model that places students at the center of learning, where they are given contextual problems that must be solved through scientific method stages (Kokotsaki et al., 2016; Sumartini, 2016). This model is designed to help students develop critical thinking skills, problem-solving abilities, and a better conceptual understanding in a more applicable manner. Savery (2015) explains that the primary characteristic of problem-based learning is encouraging students to explore, integrate theory with practice, and apply knowledge to solve real-world problems. Unlike conventional methods that focus on rote memorization, problem-based learning requires students to understand concepts more deeply and apply them in various relevant situations (Arsani et al., 2020). Additionally, research conducted by Barrows & Tamblyn, (1980) found that students who learn using problem-based learning have better problem-solving skills than those who use conventional methods. This indicates that problem-based learning can be an effective approach to enhancing conceptual understanding and analytical skills in chemistry learning.

Beyond improving problem-solving skills, the effectiveness of problem-based learning is also related to students' learning motivation. Learning motivation is an internal factor that influences the extent to which students persist in overcoming academic challenges and actively participate in the learning process (Lestari et al., 2018). High learning motivation encourages students to be more determined in understanding concepts and more prepared to solve various academic problems. However, research conducted by Dewi & Septa, (2019) indicates that a lack of variation in learning methods often causes students to lose motivation to learn, ultimately leading to poor conceptual understanding and low academic achievement. Additionally, the learning environment plays a significant role in fostering student motivation. Research findings by Mubarok (2024) show that a conducive learning environment can enhance students' enthusiasm for engaging in the learning process. Therefore, the implementation of problem-based learning is expected not only to improve problem-solving skills but also to enhance students' learning motivation through a more engaging and interactive learning approach.

Besides motivation, the effectiveness of a learning model can also be influenced by students' learning styles. Learning style is defined as an individual's preferred way of receiving, processing, and understanding information (Zapalska & Brozik, 2006). In general, learning styles can be categorized into three main types: visual, auditory, and kinesthetic (Rahman et al., 2016). Some studies suggest that learning styles can affect students' learning outcomes (Hasanah, 2018; Rusli & Rinartha, 2017). However, other studies indicate that learning styles do not have a direct impact on students' conceptual understanding (Arsani et al., 2020). These conflicting research findings suggest the need for further studies on how learning styles interact with the application of different learning models, particularly in problem-based learning.

Based on these findings, several research gaps need to be addressed. First, many students still struggle to understand the concept of salt hydrolysis, which is likely due to ineffective learning methods. Second, although problem-based learning has been proven to enhance students' understanding and problem-solving skills, limited research has examined how this model affects students' learning motivation. Third, there are inconsistent findings regarding the impact of learning styles on students' conceptual understanding, highlighting the need for further research on how learning styles interact with the implementation of problem-based learning to improve students' conceptual understanding and learning motivation.

Considering these background issues and research gaps, this study aims to analyze the impact of problem-based learning on students’ problem-solving skills and learning motivation in relation to their learning styles.

Method

The research employed a quantitative approach using a quasi-experimental method (Creswell, 2015). The research design adopted was a pretest-posttest with a control group design. This study involved one experimental class that implemented the problem-based learning model and one control class that utilized the discovery learning model. The research design is presented in Table 1.

Table 1. Research Design

Class	*Pretest*	Treatment	*Posttest*
Experimental	O_1	X1	O_2
	P_1		P_2
Control	O_1	X2	O_2
	P_1		P_2

Notes:
X1 : Learning using the problem-based learning model
X2 : Learning using the discovery learning model
O : Problem-solving ability test
P : Learning motivation questionnaire

This study was conducted at SMAN 9 Kota Bengkulu. The research focused on 11th-grade students in the 2023/2024 academic year and was carried out between February and April 2024. The study population included all 11th-grade senior high school students in Bengkulu City who met the following criteria: being enrolled in science classes (MIPA), following the national curriculum, and receiving chemistry instruction. The sample selection utilized a random sampling technique, where the experimental group consisted of students from Class XI MIPA 2, and the control group consisted of students from Class XI MIPA 1.

The research employed three primary instruments, including a problem-solving ability test, which consisted of structured questions designed to assess students’ problem-solving skills before and after the intervention. A learning motivation questionnaire was also used to measure students' motivation levels, and a learning style questionnaire was administered to categorize students based on their preferred learning styles, such as visual, auditory, or kinesthetic. The validity and reliability of all instruments were tested before implementation to ensure accurate and consistent measurements. The reliability of the instrument in this study was analyzed using the Quest program with the Cronbach's Alpha test technique. This test is used to assess the internal consistency of instruments that measure problem-solving ability, learning motivation, and learning styles. The reliability value is based on general standards, where a value of ≥ 0.70 is considered to indicate acceptable reliability.

The data collection process involved several key steps. Before the intervention, both the experimental and control groups took a pretest consisting of a problem-solving ability test and a learning motivation questionnaire to establish baseline performance. The experimental group then participated in learning sessions using the Problem-Based Learning (PBL) model, which followed structured phases, including orienting students to the problem, organizing students for learning, conducting individual or group investigations, developing and presenting the final product, and analyzing and evaluating the problem-solving process. Meanwhile, the control group underwent instruction using the Discovery Learning (DL) model, where students engaged in guided exploration and independent discovery. After completing the intervention, both groups took a posttest, which included the same problem-solving ability test and learning motivation questionnaire as in the pretest.

Data analysis was conducted using statistical methods to evaluate the effectiveness of the PBL model. Descriptive statistics, including mean, standard deviation, and percentage distributions, were calculated for each variable. The Kolmogorov-Smirnov test was applied to assess the normality of the data, while Levene’s test was used to check for homogeneity of variances. To test the research hypotheses, an Independent Sample t-Test was performed to compare posttest scores between the experimental and control groups. Additionally, Multivariate Analysis of Variance (MANOVA) was conducted to examine the interaction effects of the learning model and learning styles on problem-solving ability and motivation (Hair et al., 1995). All statistical analyses were performed using SPSS software, with a significance level of $\alpha = 0.05$ to determine the significance of the findings

Result and Discussion

The research findings indicate variations in problem-solving abilities and learning motivation between the experimental class, which implemented the Problem-Based Learning (PBL) model, and the control class, which utilized the Discovery Learning (DL) model in the salt hydrolysis topic. The data collected include students' learning styles, problem-solving abilities, and learning motivation. A summary of the average scores for problem-solving abilities and learning motivation in both the experimental and control classes is presented in Table 2.

Table 2. Description of Learning Styles, Average Problem-Solving Ability, and Learning Motivation of Students

Class	Number of Students	Learning Style			Problem-Solving Ability		Learning Motivation	
		Visual	Audio	Kinesthetic	Pretest	Posttest	Pretest	Posttest
Experimental	31	13	5	13	27.02	79.17	77.74	92.80
Control	32	13	7	12	26.3	76.43	76.65	92.46

The data indicate that both the experimental class, which applied problem-based learning, and the control class, which applied discovery learning, showed improvements in problem-solving ability and learning motivation. Before the intervention, the average problem-solving ability in both classes was relatively similar, with the experimental class scoring 27.02 and the control class 26.3. After the intervention, the experimental class achieved a higher post-test score of 79.17 compared to 76.43 in the control class, suggesting that problem-based learning may be more effective in enhancing problem-solving skills. In terms of learning motivation, both groups exhibited an increase, with the experimental class rising from 77.74 to 92.80 and the control class from 76.65 to 92.46. This indicates that while both teaching models positively influenced motivation, the experimental class demonstrated slightly greater improvement. These results suggest that problem-based learning provides a more structured approach that supports both conceptual understanding and engagement in learning.

Problem-solving ability data were obtained from the results of the pretest and posttest on the salt hydrolysis material. The posttest consisting of six limited essay questions was conducted in the final session to assess students' problem-solving abilities after treatment. The average pretest and posttest scores for the experimental and control classes are presented in Table 3.

Table 3. Description of Problem Solving Ability Data

Category	Pretest		Posttest	
	Experimental	Control	Experimental	Control
Lowest Value	16.67	12.5	58.33	58.33
The highest score	41.67	37.5	95.83	91.67
Average	27.02	26.3	79.17	76.43
Average Difference		Experimental		Control
		52.15		50.13

Table 3 illustrates differences in students' problem-solving abilities between the experimental and control classes. The pretest average scores were 27.02 in the experimental class and 26.3 in the control class. After treatment, the posttest averages increased to 79.17 and 76.43, respectively. The difference between posttest and pretest scores was 52.15 for the experimental class and 50.13 for the control class. These results indicate that both learning models contributed to improving students' problem-solving abilities. However, the higher average score in the experimental class suggests that the problem-based learning model was more effective in enhancing problem-solving skills compared to the discovery learning model.

Students' learning motivation was assessed using a questionnaire administered before and after applying the PBM model in the experimental class and the DL model in the control class. The questionnaire consisted of 22 statements, with scores ranging from 1 to 5. A detailed description of the average learning motivation scores for both classes is presented in Table 4.

Table 4. Description of Learning Motivation Data

Category	Before Treatment		After Treatment		Average Difference	
	Experimental	Control	Experimental	Control	Experimental	Control
Average	77.74	76.65	92.80	92.46	15.25	15.90

Based on Table 4, the average learning motivation score before treatment was 77.74 in the experimental class and 76.65 in the control class. After treatment, the scores increased to 92.80 and 92.46, respectively. The score difference was 15.25 for the experimental class and 15.90 for the control class.

Students' learning styles were analyzed using a questionnaire completed before the application of the PBM model in the experimental class and the DL model in the control class. The questionnaire consisted of 11 items with three answer choices representing visual, auditory, and kinesthetic learning styles. The classification results are presented in Table 5.

Table 5. Description of Learning Style Data

Class	Learning Style			Number of Students
	Visual	Audio	Kinesthetic	
Experimental	13	5	13	31
Control	13	7	12	32

Based on Table 5, the learning styles distribution in the experimental class includes 13 visual, 5 auditory, and 13 kinesthetic learners, while the control class has 13 visual, 7 auditory, and 12 kinesthetic learners, showing a balanced distribution.

Before performing the MANOVA test, prerequisite checks such as outlier detection, normality, and homogeneity tests were conducted to ensure valid and reliable analysis. These tests identify extreme values, verify data normality, and confirm equal variance-covariance matrices across groups—critical assumptions for applying MANOVA and obtaining accurate results. The results of the univariate and multivariate outlier tests in this study are presented in the figure 1 and 2.

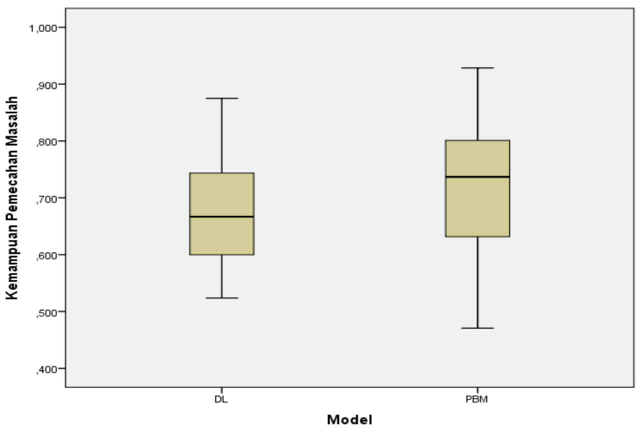

Figure 1. Box Plots of Problem Solving Ability of Experimental and Control Classes

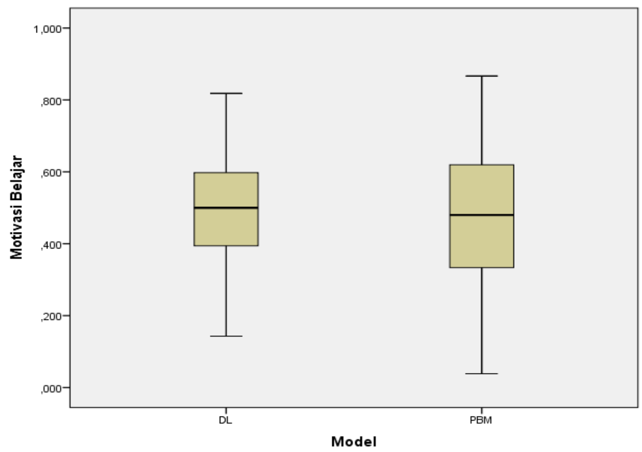

Figure 2. Box Plots of Learning Motivation in Experimental and Control Classes

Based on Figures 1 and 2 above, the boxplots indicate no univariate outliers in problem-solving ability and learning motivation data, as no points fall outside the whiskers in both the Discovery Learning (DL) and Problem-Based Learning (PBM) groups. Additionally, multivariate outliers were assessed using the Mahalanobis distance, where a value smaller than CHIINV (13.8155) indicates no multivariate outliers. In this study, the highest Mahalanobis distance obtained was 7.47079, which is less than 13.8155, confirming that the data do not contain multivariate outliers. The next step is to assess normality, which the researcher evaluated based on Table 6.

Table 6. Results of the Normality Test of Problem Solving Ability and Learning Motivation

Variable		Class	Statistic	Df	Sig
Problem Solving	Pretest	Experimental	.945	31	.115
		Control	.950	32	.142
	Postest	Experimental	.950	31	.153
		Control	.963	32	.327
Learning Motivation	Before treatment	Experimental	.984	31	.919
		Control	.976	32	.693
	After Treatment	Experimental	.977	31	.726
		Control	.972	32	.567

Based on Tables 6, the significance values for the pretest-posttest problem-solving ability and learning motivation data in both the experimental and control classes are greater than 0.05. This indicates that the null hypothesis (H0) is accepted, meaning the data come from a normally distributed population. To prove homogeneity between the two groups, the researcher analyzes Table 7.

Table 7. Homogeneity Test of Pretest and Posttest Data for the experimental and control classes

Data	Box's M	F	Sig
Pre-test	.323	.104	.958
Post-test	.683	.220	.883

The homogeneity of the pretest and posttest data was tested using Levene's test. The obtained significance values of 0.958 and 0.883, both greater than 0.05, indicate no significant difference in variance between groups, confirming that the data come from a homogeneous population. This ensures that further statistical analysis can be conducted under the assumption of homogeneity.

After ensuring that the MANOVA assumptions are met, the next step is to validate the previously formulated hypothesis by analyzing the results of the Multivariate Test, as shown in Table 8.

Table 8. Results of the Hotelling's Trace Multivariate Test

Effect	Value	Hypothesis df	Sig.	Partial Eta Squared
Hotelling's Trace	.031	2.000	.403	.030

Based on the multivariate test results in Table 8, the significance value of 0.403 (> 0.05) indicates no significant simultaneous difference in problem-solving ability and learning motivation between students taught using problem-based learning and discovery learning models. The learning model accounts for only 3% of the variance in these outcomes, as shown by the partial eta squared value of 0.030.

Next, the researcher conducts a follow-up test to analyze the differences in each dependent variable separately. This is done by examining the Test of Between-Subjects Effects in the SPSS output, which provides insights into the individual impact of the learning models on problem-solving ability and learning motivation.

Table 9. Tests of Between-Subjects Effects

Variable	Mean Square	F	Sig.	Partial Eta Squared
Problem Solving	.018	1.479	.229	.024
Learning Motivation	.009	.223	.631	.004

Based on the multivariate test results in Table 9, there is no significant difference in problem-solving ability (p = 0.229) or learning motivation (p = 0.631) between students taught using problem-based learning and discovery learning models. The learning model contributes only 2.4% to problem-solving ability and 0.4% to learning motivation, indicating minimal impact on these outcomes.

To address these research questions, further analysis is conducted using a Two-Way ANOVA in SPSS with a significance level of 0.05. This analysis aims to examine the interaction effect between the applied learning model and students' learning styles on problem-solving ability and learning motivation, as presented in Table 10.

Table 10. Learning Interaction Model with Learning Styles on Problem Solving Ability and Learning Motivation

Variable	Source	Mean Square	F	Sig.	Partial Eta Squared
Problem Solving	Model*Gaya Belajar	.018	1.654	.201	.056
Learning Motivation	Model*Gaya Belajar	.001	.029	.971	.001

Based on Table 10, the obtained significance values for problem-solving ability and learning motivation are 0.201 and 0.971, respectively, both exceeding 0.05. This indicates that the null hypothesis is accepted, meaning there is no significant interaction between the learning model and students' learning styles in influencing either problem-solving ability or learning motivation. Furthermore, the partial eta squared values of 0.056 for problem-solving ability and 0.001 for learning motivation suggest that the combined effect of the learning model and learning styles contributes 5.6% to problem-solving ability and only 0.1% to learning motivation.

To investigate this issue, further analysis was conducted to determine whether significant differences exist in problem-solving ability and learning motivation among students with visual, auditory, and kinesthetic learning styles. The results were examined using a multivariate test in SPSS, specifically Wilks' Lambda, as the analysis involved more than two independent variable groups. This test was chosen because the variance-covariance matrix homogeneity assumption was met, and the research data followed a normal distribution. The detailed results of this analysis can be seen in Table 11.

Table 11. Results of Multivariate Learning Style Test

Effect	Value	Hypothesis df	Sig.	Partial Eta Squared
Wilk's Lambada	.845	4.000	.043	.081

Based on Table 11, the significance value of 0.043 (<0.05) indicates a significant difference in problem-solving ability and learning motivation among students with visual, auditory, and kinesthetic learning styles. The partial eta squared value of 0.081 shows that learning styles contribute 8.1% to the variance in problem-solving ability and motivation, suggesting that other factors also influence these outcomes. This study compares the implementation of problem-based learning and discovery learning models to examine their effects on students' motivation and problem-solving ability in the topic of salt hydrolysis, analyzing the differences in pretest and posttest scores as well as motivation questionnaire scores collected before and after the learning process.

The first finding in this study reveals no significant difference in problem-solving ability and learning motivation between students taught using the problem-based learning model and those taught using the discovery learning model. The data were analyzed using a MANOVA with Hotelling's Trace, which yielded a significance value of 0.403 ($p > 0.05$), indicating that the two instructional models did not produce statistically different outcomes when assessed simultaneously. This finding aligns with Lena et al (2022) who found that both models enhance student learning without significant differences in effectiveness. Various factors could explain this result, including students' learning attitudes and classroom conditions, as suggested by Nguyen et al. (2023). One notable aspect in this study was the scheduling of some experimental group sessions in the afternoon, following the midday break and Dhuhr prayer. Research by Escribano & Díaz-Morales, (2016) and Safitri (2023) highlights that cognitive performance is generally higher in the morning, whereas learning conducted in the afternoon can be less effective due to student fatigue and reduced attention . This scheduling issue may have limited the potential impact of the problem-based learning model on students' problem-solving abilities and learning motivation.

Additionally, the partial eta squared value obtained from Table 8 was 0.030 (3%), classifying the instructional model's effect as small. This suggests that while problem-based learning and discovery learning may contribute to learning outcomes, their overall impact remains limited within the scope of this study. One contributing factor is the short implementation period, as problem-based learning was applied in only four sessions. Giva & Duma, (2015) emphasize that problem-based learning requires a longer duration to yield meaningful improvements in students' cognitive development and motivation. The restricted timeframe in this study likely reduced the effectiveness of the intervention, limiting the depth of engagement and critical thinking development that this model typically fosters. Future research should consider a more extended implementation period to explore whether prolonged exposure to problem-based learning produces more substantial gains in students' problem-solving abilities and learning motivation.

The second finding of this study reveals that there is no significant difference in problem-solving ability between students in the experimental and control groups. The results from the Test of Between-Subjects Effects indicate a significance value of 0.229 ($p > 0.05$), confirming that the application of problem-based learning and discovery learning did not lead to statistically significant differences in students' problem-solving abilities. However, previous research suggests that problem-based learning can positively influence students' problem-solving skills (Almulla, 2019; Surur et al., 2020; Yung & Chi-Chia, 2015). Harapit, (2018) also found that problem-based learning contributes to the improvement of problem-solving ability and learning motivation, though its effectiveness may not always result in significant statistical differences when compared to other active learning models. Similarly, Hidaayatullaah et al., (2020) and Dağyar & Demirel, (2015) highlight that problem-based learning has been shown to enhance students' problem-solving skills. The absence of significant differences in this study may be attributed to various factors, including the time constraints of implementing problem-based learning and the students' adaptability to different instructional models.

Furthermore, no significant difference in learning motivation was found between the experimental and control groups ($p = 0.631$), indicating that problem-based and discovery learning had similar impacts. This aligns with previous studies highlighting PBL's role in supporting motivation, engagement, and collaborative learning, though its advantage may not always be statistically distinct (Al-Bahadli et al., 2023; Chang & Jang, 2019; Shiddiqi & Setiyawan, 2024). Additionally, research by De Witte & Rogge, (2016) and (Schmidt et al., (2011) supports the notion that problem-based learning positively impacts students' academic performance and motivation. Meanwhile, discovery learning is recognized for fostering active engagement by allowing students to construct their own knowledge through exploration and reasoning (Stoffová, 2020). Research also suggests that discovery learning is associated with high levels of student participation and responsiveness, contributing to increased engagement (Rudibyani & Perdana, 2018). These findings indicate that while both instructional models support student motivation and active learning, their effects on motivation do not differ significantly in this study.

The interaction between problem-based learning (PBL) and students' learning styles was examined using Two-Way ANOVA. Results showed no significant interaction for problem-solving ability ($p = 0.201$) or learning motivation ($p = 0.971$). This indicates that the influence of the learning model and learning styles on students' cognitive and motivational outcomes operates independently. Thus, while both factors impact learning, they do not amplify or diminish each other's effects (Taş & Minaz, 2024). Consequently, both PBL and discovery learning provide comparable benefits regardless of whether students have visual, auditory, or kinesthetic learning preferences.

The results show significant differences in problem-solving and motivation across learning styles ($p = 0.043$), highlighting their impact on learning outcomes. PBL proves effective in supporting these skills across diverse learners (Rosiyanti et al., 2021). Additionally, research suggests that students with different learning styles demonstrate varying levels of problem-solving ability (Juniati & Budayasa, 2022). This study supports that visual learners, with the highest problem-solving score

(80.44), may have a cognitive edge due to their strength in processing visual-spatial information, enhancing analysis and understanding.

Visual learners showed the highest scores in both problem-solving (93.57) and motivation, followed by kinesthetic (93.16) and auditory learners (91.40). These results indicate a link between higher problem-solving ability and stronger learning motivation, highlighting the interplay between cognitive skills and engagement. This trend aligns with research conducted by Hindrasti, (2013) and Ibrahim & Hussein, (2016), The findings show that kinesthetic learners outperform auditory learners, emphasizing the need to align instruction with students' learning styles, as these influence both cognition and motivation, impacting overall achievement.

Conclusion

Based on the research findings, the application of Problem-Based Learning (PBL) and Discovery Learning (DL) does not result in a significant difference in students' problem-solving abilities and learning motivation, either simultaneously or individually. The statistical analysis revealed that the effective contribution of PBL to problem-solving ability was only 2.4%, while its contribution to learning motivation was 0.4%, indicating that other external and internal factors play a more dominant role in shaping these outcomes. Furthermore, no interaction was found between learning models and learning styles in influencing students' problem-solving abilities and motivation. However, a significant difference was identified among students with different learning styles, where visual learners outperformed their auditory and kinesthetic counterparts in both problem-solving ability and motivation. These findings suggest that students' preferred modes of information processing significantly impact their cognitive and affective learning outcomes. Future research should explore additional factors that contribute to students' problem-solving abilities and motivation, such as cognitive load, metacognitive strategies, or classroom engagement. Moreover, investigating the long-term impact of PBL and DL on students' conceptual understanding and retention of knowledge could provide deeper insights into their effectiveness. Further studies could also examine how different instructional interventions or blended learning approaches may optimize these models to better cater to students with diverse learning styles, ultimately enhancing both problem-solving skills and motivation in a more sustainable manner.

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All authors contributed equally to the writing of this manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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