JPPIPA 12 (7) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of Problem Based Learning Model and Learning Styles on Motivation and Learning Outcomes in Acid-Base of Grade XI Students at SMA Negeri 18 Makassar

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Received: May 15, 2026
Revised: June 24, 2026
Accepted: August 03, 2026
Published: August 03, 2026

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DOI: 10.29303/jppipa.v12i7.15698

Abstract: This study is a quasi-experimental research aimed to determine the effect of problem based learning model and learning styles on motivation and learning outcomes in acid-base of grade students XI at SMA Negeri 18 Makassar. The research design used is a factorial design 2×3. The research sample consisted of 60 students of grade XI who were divided into experimental groups and control groups. The sampling technique was carried out by random sampling. The data obtained were analyzed using descriptive and inferential statistics. The results of the study show that the problem based learning model has a significant effect on learning motivation and learning outcomes. Learning styles also has a significant effect on learning motivation and learning outcomes. In addition, the problem based learning model and learning style simultaneously had a significant effect on both bound variables. This shows that there is the effect of problem based learning and learning styles on motivation and learning outcomes in acid-base of grade XI students at SMA Negeri 18 Makassar.

Keywords: Problem based learning model, learning style, learning motivation, learning outcomes.

Introduction

Chemistry, one of the parts of science subjects, is often considered difficult by students, one of the reasons is the abstract nature of the material so that it requires deep conceptual reasoning skills. When learning is not associated with phenomena that are close to daily experiences, students tend to have difficulty imagining and constructing the meaning of the concepts learned, as a result of which the learning process feels heavy, thus reducing students' motivation to learn and having implications for low learning outcomes.

Acid-base material is one of the chemical subject matter taught in grade XI. This material is abstract because students must understand the concept of acid-base theory. As well as ionization characteristics and acid-base strength that cannot be observed directly. The abstract character of the concept of acid-base makes it difficult for students to identify the type of acid-base in a reaction, determine the pH of the solution, and interpret the particle interactions that occur, namely how molecules and ions in the solution interact.

Ideally, the learning process is designed to foster the active involvement of students in constructing knowledge so that they not only understand the material but also have a positive attitude towards learning activities and encourage the achievement of optimal learning outcomes. However, this condition has not been fully achieved in the process of learning chemistry in schools. Based on the results of observations at SMA Negeri 18 Makassar, the learning conditions still do not fully reflect the student-centered learning process. In the learning process, students are still found who have difficulty understanding chemistry materials, especially when faced with problems that require reasoning skills.

The results of the learning evaluation of students in one class show different variations. Some students are able to achieve good learning results, but others still

How to Cite:
Rahman, S. Z. D., Sudding, & Sugiarti. (2026). The Effect of Problem Based Learning Model and Learning Styles on Motivation and Learning Outcomes in Acid-Base of Grade XI Students at SMA Negeri 18 Makassar. *Jurnal Penelitian Pendidikan IPA*, *12*(7), 389–399. https://doi.org/10.29303/jppipa.v12i7.15698

have difficulty in understanding the material studied. The average acquisition of students' learning outcomes has not reached the optimal results as shown by the score below the Minimum Completeness Criteria (KKM) set by the school, which is 80. This suboptimal learning outcome indicates that the problem lies not only in the mastery of the material, but also in the learning process experienced by students during the learning process that does not accommodate the needs and learning characteristics of students.

In addition to having an impact on learning outcomes, these learning conditions also have implications for students' learning motivation. Ideally, students with high learning motivation will show great interest in lessons, try to understand concepts in depth and not give up easily when facing difficulties, on the other hand, students with low motivation tend to be passive, lack focus, and only learn to meet the demands of evaluation alone. Facts in the field show that the level of students' motivation to learn in chemistry subjects is still in the low category. This low motivation to learn shows that students have not been fully actively involved in the chemistry learning process. This can be seen that some students show high enthusiasm in learning, but not a few are passive, have minimal participation and only follow the direction of educators. The results of the observation show that this condition occurs because learning activities are still dominated by the delivery of concepts in an abstract manner and are less associated with the context of daily life and focus on solving problems so that the opportunity for students to be actively involved in exploring concepts, expressing opinions, and building understanding independently is still limited.

Difficulty in understanding material concepts decreases confidence, interest and drive to learn. This condition has an impact on low motivation to learn. Learning motivation affects how learners manage their learning process and their ability to survive difficulties in learning chemistry. This is in line with the results of research that show that students' low self-ability will reduce active involvement and learning motivation (Safitri et al., 2023). Thus, the low involvement of students in the learning process is reflected in the learning motivation indicator because in the learning process there is a lack of gradual exercise, feedback, and space for independent learning so that it does not fully provide space for students to play a role as learning subjects.

The difference in the level of learning motivation between students also shows that there is a variation in learning characteristics that have not been accommodated in the learning process. Each student has a different learning style in receiving, processing and understanding information. Adjusting learning to the characteristics of students' learning styles has been proven to be able to improve learning outcomes (Kamba et al., 2024). This indicates that the suitability between the learning model and the learning style of students optimizes learning outcomes. So that some students have difficulty in participating in learning optimally. This is in line with the theory of visual, auditory, and kinesthetic learning styles which states that the compatibility between learning styles and learning strategies can increase students' engagement and motivation to learn (Simanungkalit et al., 2024).

Efforts to overcome this problem are the application of a learning model that is not only oriented to the delivery of material but also able to relate concepts to real problems and accommodate differences in students' learning styles. The Problem Based Learning model is one of the learning models that emphasizes solving real problems as the first step in building new knowledge, encouraging cooperation, and active involvement of students and providing opportunities for students to learn according to their learning characteristic analyze problems, develop arguments, and make decisions based on the data or concepts learned. The steps in implementing the Problem Based Learning model include: (1) orientation of students to problems, (2) organizing for learning, (3) independent and group investigations, (4) development and presentation of works, and (5) analysis and evaluation of the problem-solving process (Liska et al., 2024). Thus, the application of the Problem Based Learning model reviewed from the learning style is expected to increase students' learning motivation and learning outcomes in acid-base materials. The Problem Based Learning model is effective in improving the understanding of chemistry concepts at the high school level (Zainuddin, 2024).

Based on the background description, a study will be conducted on the influence of the Problem Based Learning model and learning style on the learning motivation and acid-base learning outcomes of class XI students of SMA Negeri 18 Makassar.

Method

This research is a quantitative research with a quasi-experimental approach. This research was carried out in one of the State High Schools (SMAN) in Makassar City that has been accredited A. This school is located in the Biringkanaya District area in the even semester of the 2025/2026 school year following the learning schedule that has been set in the classroom. The research design used is a 2*3 factorial design. The design of this research involves two factors and each factor involves two levels (levels). The combination between these levels of factors

forms several groups of treatments that are analyzed simultaneously can be seen in Table 1.

Table 1. Research Design

Learning Style (B)	Learning Model (A)	
	Model *Problem Based Learning* (A1)	Direct Learning Model (A2)
Visual (B_1)	Y_1 Y_2 [A_1B_1]	Y_1 Y_2 [A_2B_1]
Auditorium (B_2)	Y_1 Y_2 [A_1B_2]	Y_1 Y_2 [A_2B_2]
Kinesthetics (B_3)	Y_1 Y_2 [A_1B_3]	Y_1 Y_2 [A_2B_3]
Σ	Y_1 Y_2 [A_1B_1] + Y_1 Y_2 [A_1B_2] + Y_1 Y_2 [A_1B_3]	Y_1 Y_2 [A_2B_1] + Y_1 Y_2 [A_2B_2] + Y_1 Y_2 [A_2B_3]

Description:

Y_1 : Learning motivation
Y_2 : Chemistry learning outcomes
A : Learning model
A_1 : Problem Based Learning Model
A_2 : Direct Instruction Model
B : Learning style
B_1 : Visual learning style
B_2 : Auditory learning style
B_3 : Kinesthetic learning style
A_1B_1 : A group of students taught using the Problem Based Learning model with a visual learning style
A_1B_2 : A group of learners taught using the Problem Based Learning model with an auditory learning style
A_1B_3 : Groups of students taught using the Problem Based Learning model with kinesthetic learning style
A_2B_1 : A group of learners taught using a Direct learning model with a visual learning style
A_2B_2 : Groups of learners taught using the Direct learning model with auditory learning style
A_2B_3 : A group of students who are taught using a Direct learning model with a kinesthetic learning style.

The population in this study is all students in XI of SMA Negeri 18 Makassar for the 2025/2026 school year. The research sample was determined by random sampling technique so that class XI.1 as an experimental group was given treatment for the application of the Problem Based Learning model and class XI.2 as a control group was given the application of the Direct learning model.

The data of this study was collected using a learning motivation and learning style questionnaire, cognitive learning outcome tests, affective learning outcome observation sheets, psychomotor, and learning implementation. Before being used, all instruments have been tested for validity and reliability to ensure the feasibility of the instrument in measuring research variables. The research data was analyzed using descriptive and inferential statistics. Descriptive statistical data was used to describe the data on students' learning styles, learning motivation, and acid-base learning outcomes. Inferential analysis begins with a prerequisite test which includes normality and homogeneity tests. Furthermore, hypothesis testing was carried out using the Two-Way ANOVA test at a significance level of $\alpha = 0.05$ to determine the influence of problem based learning models and learning styles on the motivation and acid-base learning outcomes of grade XI students of SMA Negeri 18 Makassar.

Result and Discussion

The results of the research presented include descriptive statistics, analytical prerequisite tests, and hypothesis tests. The discussion was conducted to interpret research findings related to the description of learning styles, the influence of the Problem Based Learning model and learning style on motivation and acid-base learning outcomes. This research was carried out at SMA Negeri 18 Makassar.

Description of learning styles

The grouping of students' learning styles was obtained from the results of the learning style questionnaire that had been given before the implementation of learning. The grouping aims to identify the tendency of each student's learning style which includes visual, auditory, and kinesthetic learning styles. The distribution of students' learning styles can be seen in Table 2.

Table 2. Distribution of Learners' Learning Styles in the Experimental Group and the Control Group

Learning Style	Number of Students			
	Experimental Group		Control Group	
	F	P%	F	P%
Visual	12	40	9	30.00
Auditory	8	26.67	11	36.67
kinesthetic	10	33.33	10	33.33

Based on Table 2, it is known that in the experimental group, most of the students have a visual learning style, while the control group is more inclined to an auditory learning style.

Description of learning motivation

Students' learning motivation was measured using a learning motivation questionnaire given after the implementation of learning. The results of the descriptive analysis of students' learning motivation in

the experimental group and the control group based on learning style can be seen in Table 3.

Table 3. Results of Descriptive Statistical Analysis of Learning Motivation in the Experimental Group and Control Group

Learning Style	Learning Model	Statistics		
		Mean	Std. Deviation	N
Visual	Problem Based Learning	81.11	6.25	12
	Direct Instruction Model	57.77	6.66	9
	Total	71.11	13.38	21
Auditory	Problem Based Learning	65	6.90	8
	Direct Instruction Model	81.21	6.54	11
	Total	74.38	10.48	19
Kinesthetics	Problem Based Learning	87.33	6.62	10
	Direct Instruction Model	64.66	6.32	10
	Total	76	13.22	20

Based on Table 3, it can be seen that the highest average learning motivation is found in students with kinesthetic learning styles in the experimental group, namely the Problem Based Learning model. From the results of the calculation of the learning motivation questionnaire, a frequency distribution based on the category can be seen in Table 4.

Table 4. Frequency Distribution of Learning Motivation

Criteria Range	Model Problem Based Learning		Direct Instruction Model	
	F	P%	F	P%
Very High	11	36.67	5	16.67
Height	16	53.33	15	50
Medium	3	10	10	33.33
Low	0	0	0	0

Based on table 4, it shows that the students' learning motivation obtained after being given each treatment by applying the Problem Based Learning model in the experimental class and the direct learning model in the control class, namely students in the experimental class have higher motivation compared to the control class.

Table 5. Pretest and Posttest Descriptive Statistical Data

Statistic	Test Result			
	Experiment Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Number of student	30	30	30	30
Highest score	39	92	39	87
Lowest score	22	71	21	69
Average score	31.80	83	27.17	77.33
Median	33	84	26.50	76.50
Mode	33	82	24	70
Standard deviation	5.34	6.30	4.68	5.60

Description of learning outcomes

The data on the learning outcomes of students in the experimental group were taught using the Problem Based Learning model, while the control group was taught using the direct learning model on acid-base material was analyzed based on the pretest and posttest scores of students using descriptive statistics. Therefore, the results of the descriptive analysis of cognitive learning outcomes can be seen in Table 5.

The learning outcomes of students are then grouped based on the criteria for the completeness of the learning outcomes of grade XI of SMA Negeri 18 Makassar can be seen in Table 6.

Table 6. Criteria for Completeness of Student Learning Outcomes

Value	Criteria	Experimental Group			
		Pretest		Posttest	
		F	P%	F	P%
≥ 80	Completed	0	0	22	73.33
< 80	Not completed	30	100	8	26.67
Total		30	100	30	100
Value	Criteria	Control Group			
		Pretest		Posttest	
		F	P%	F	P%
≥ 80	Completed	0	0	11	36.67
< 80	Not completed	30	100	19	63.33
Total		30	100	30	100

Table 6 shows that the completeness of students' learning outcomes in the experimental group learned using the Problem Based Learning model was higher than the completeness of the students' learning outcomes in the control group learned using the direct learning model. So that the completeness of the cognitive learning outcomes of students in the experimental group based on learning style can be seen in Table 7.

Table 7 completeness of student learning outcomes based on learning style shows that students who are taught using the Problem Based Learning model are higher with an average of 7.33 compared to students who are taught using the direct learning model with an average score of 3.67. Furthermore, to determine the level of achievement of students in each indicator of cognitive learning outcomes obtained by students in the experimental group and the control group is classified based on the achievement of the indicators, The data if presented in the visualization of the percentage of the diagram can be seen in Figure 1.

Table 7. Completeness of Student Learning Outcomes Based on Learning Style

Learning Model	Learning Style			Mean
	Visual	Auditory	Kinesthetic	
Problem Based Learning	12	0	10	7.33
Direct Instruction Model	0	11	0	3.67
Total	12	11	10	11

Figure 1 show that in the experimental group of ten indicators of competency achievement there were four indicators that were complete and there were six indicators that were incomplete, while in the control group of ten indicators of competency achievement there were four indicators that were complete and there were six indicators that were incomplete. The indicator is classified completely if it reaches a ≥ score percentage of 80 according to the criteria for the completeness of the acid-base material class for grade XI students of SMA Negeri 18 Makassar.

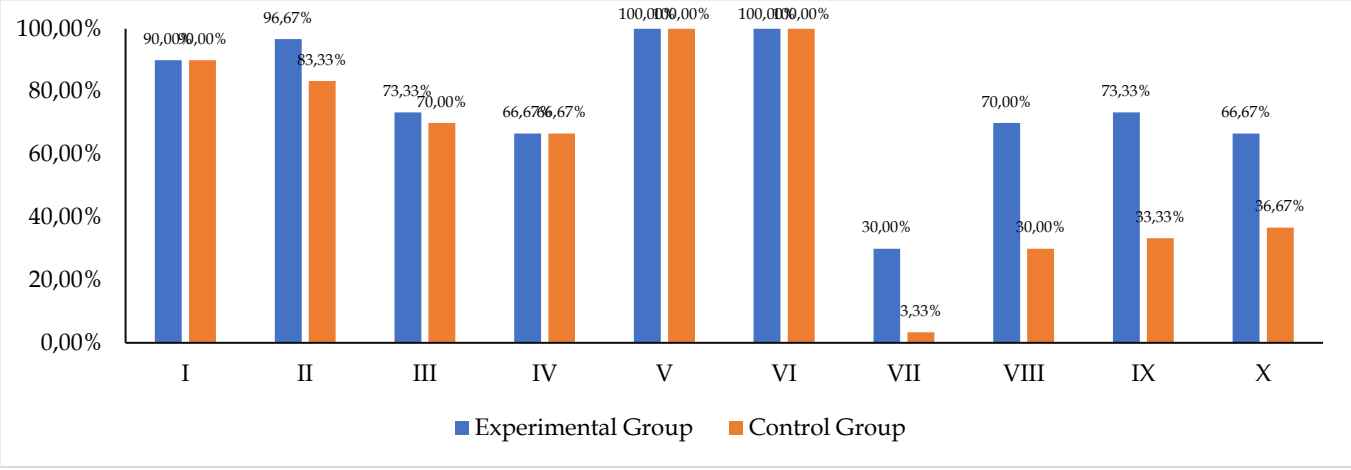

Figure 1. Percentage Completeness Chart of Each Indicator

Furthermore, the descriptive data of Normalized gain (N-gain) of students' learning outcomes after learning using the Problem Based Learning model in the experimental group and the direct learning model in the control group were taken from the students' pretest and posttest data. The results of data processing showed that the average N-gain score of students after learning using the Problem Based Learning model on acid-base material was 0.74 in the experimental group while the direct learning model was 0.69. The percentage increase in students' cognitive learning outcomes can be seen in Table 8.

Table 8. N-gain Cognitive Learning Outcomes of Learners

Coeficient Normalization	Classification	Experiment Group		Control Group	
		Frequency	Percentage %	Frequency	Percentage
g > 0.7	Height	20	66.67	12	40.00%
0.3 < g ≤ 0.7	Medium	10	33.33	18	60.00%
g ≤ 0.3	Low	0	0	0	0%

Table 9. Percentage of Students' Affective Learning Outcomes

Learning Style	Learning Model	Statistics		
		Mean	Std. Deviation	N
Visual	Problem Based Learning	91.72	3.43	12
	Direct Instruction Model	78.03	2.71	9
	Total	85.85	2.88	21
Auditory	Problem Based Learning	82.51	2.86	8
	Direct Instruction Model	79.96	2.50	11
	Total	81.04	2.88	19
Kinesthetics	Problem Based Learning	88.66	2.63	10
	Direct Instruction Model	78.98	2.56	10
	Total	83.82	5.57	20

Students' learning outcomes are not only reviewed from the cognitive realm but also from the affective and psychomotor realm through observation sheets during the learning process. Based on the observation analysis of affective learning outcomes in the experimental class and the control class, the percentage can be seen in Table 9.

From the results of the observation analysis, a frequency distribution based on the category can be seen in Table 10.

Table 10. Frequency Distribution of Affective Learning Outcomes

Criteria Range	Model Problem Based Learning		Learning Model	
	F	P%	F	P%
Excellent	28	93,33%	10	33,33%
Good	2	6,67%	20	66,67%
Enough	0	0%	0	0%
Less	0	0%	0	0%

The assessment of learning outcomes is then carried out in the psychomotor realm of students during learning activities. The results of the analysis of psychomotor learning outcomes in the experimental class and the control class were obtained as a percentage which can be seen in Table 11.

Table 11. Percentage of Students' Psychomotor Learning Outcomes

Learning Style	Learning Model	Statistics		
		Mean	Std. Deviation	N
Visual	Problem Based Learning	92.36	3.90	12
	Direct Instruction Model	74.07	2.77	9
	Total	84.52	9.87	21
Auditory	Problem Based Learning	83.33	3.15	8
	Direct Instruction Model	66.66	3.22	11
	Total	73.68	9.00	19
Kinesthetics	Problem Based Learning	95.83	3.40	10
	Direct Instruction Model	60.83	2.91	10
	Total	79.02	18.21	20

From the results of the observational analysis, a frequency distribution based on the category can be seen in Table 12.

Table 12. Frequency Distribution of Psychomotoric Learning Outcomes

Criteria Range	Model *Problem Based Learning*		Direct Instruction Model	
	F	P%	F	P%
Excellent	28	93.33	0	0
Good	2	6.67	26	86.67
Enough	0	0	4	13.33
Less	0	0	0	0

Results of Observation of Learning Implementation

Descriptive analysis of the results of observation of learning implementation using *the Problem Based Learning* model in the experimental group and the control group only used the direct learning model which was carried out four times. Based on the results of the observation of learning implementation obtained, the average percentage of learning implementation is at the very good criteria shown in Table 13.

Table 13. Average Percentage of Learning Implementation

Meetings	Model Problem Based Learning		Direct Instruction Model	
	P%	Information	P%	Information
I	100	Excellent	100	Excellent
II	92.59	Excellent	95.23	Excellent
III	96.29	Excellent	100	Excellent
IV	100	Excellent	80.95	Excellent
Average	97.22	Excellent	94.04	Excellent

Prerequisite Test

Before conducting the hypothesis test, a prerequisite test was carried out consisting of a normality test and a homogeneity test on the motivation and learning outcomes of students in the experimental group and the control group.

The normality test is carried out to find out whether the research data is distributed normally or not. Normality testing was carried out using *the Shapiro-Wilk test* at a significance level of 0.05 with the help of SPSS. The results of the normality test obtained can be seen in Table 14.

Table 14. Normality Test Result

Variable	Say.	Information
Standardized Residual for Learning Motivation	0.106	Normal
Standardized Residual for Cognitive Learning Outcomes	0.353	Normal
Standardized Residual for Affective Learning Outcomes	0.355	Normal
Standardized Residual for Psychomotor Learning Outcomes	0.16	Normal

Table 14 shows that the significance value of all research variables is greater than 0.05. These results indicate that residual data is distributed normally so that the assumption of normality is met.

The homogeneity test was carried out to find out the similarity of variance between groups. The test was carried out using *the Levene's Test* at a significance level of 0.05. The results of the homogeneity test are presented in Table 15.

Table 15. Homogeneity Test Result

Variable	Say.	Information
Learning Motivation	0.998	Homogeneous
Cognitive Learning Outcomes	0.945	Homogeneous
Affective Learning Outcomes	0.628	Homogeneous
Psychomotor Learning Outcomes	0.942	Homogeneous

Table 15 shows that the significance value obtained by the research variable is greater than 0.05. These results indicate that the data between groups are homogeneous so that the homogeneity assumption is met.

Hypothesis Test

Based on the results of the prerequisite test, it is known that the data in the experimental and distributed control classes are normal and that the two classes have homogeneous variance. Therefore, hypothesis testing was continued using Two-way ANOVA analysis at a significance rate of 0.05. The results of the hypothesis testing are presented in Table 16.

Table 16. Hypothesis Test Result Learning Motivation

Variables	Sig.	Remarks
Learning Model	0.000	H_0 is rejected, H_1 is accepted
Learning Style	0.000	H_0 is rejected, H_1 is accepted
Interaction of Learning Models and Learning Styles	0.000	H_0 is rejected, H_1 is accepted

Table 17. Hypothesis Test Result Learning Outcomes

Variables	Cognitive		Affective		Psychomotoric	
	Sig.	Information	Sig.	Information	Sig.	Information
Learning Model	0.000	H_0 is rejected, H_1 is accepted	0.000	H_0 is rejected, H_1 is accepted	0.000	H_0 is rejected, H_1 is accepted
Learning Style	0.009	H_0 is rejected, H_1 is accepted	0.001	H_0 is rejected, H_1 is accepted	0.000	H_0 is rejected, H_1 is accepted
Interaction of Learning Models and Learning Styles	0.000	H_0 is rejected, H_1 is accepted	0.000	H_0 is rejected, H_1 is accepted	0.000	H_0 is rejected, H_1 is accepted

Decision making on hypothesis testing is carried out based on significance values. H_0 is rejected if the significance value is less than 0.05, while H_0 is accepted if the significance value is less than 0.05. Based on the table of the defense model, it has a significant effect on the motivation and learning outcomes of students. These

influences are shown in the cognitive, affective, and psychomotor domains. Learning style also shows a significant influence on motivation and the three domains of learning outcomes are covered. In addition, there is an interaction between learning models and learning styles on the motivation of the students and learning outcomes in the cognitive, affective, and psychomotor domains of students.

The Effect of the Problem Based Learning Model on Motivation to Learn About Acids and Bases

The results of the study indicate that the Problem Based Learning model has a significant effect on the motivation to learn about acids and bases among grade XI students at State High School 18 Makassar. The difference in the average learning motivation scores indicates that students who participated in Problem Based Learning tended to have higher learning motivation compared to those who participated in direct instruction. This difference in learning motivation occurs because the Problem Based Learning model presents students with contextual problems closely related to daily life as the first step in building new knowledge. Motivation serves as the driving force that directs and sustains a person's learning behavior, keeping them focused on achieving desired outcomes (Slavin, 2018). Thus, the problems presented encourage students to seek information, discuss, express opinions, and find solutions both independently and in groups. Learners' active involvement in these learning activities fosters a sense of responsibility for the tasks at hand, thereby increasing their interest and drive to learn. In the learning process, motivation provides energy and direction for learners' actions, giving them the drive to actively participate in learning activities (Santrock, 2018).

In addition, the characteristics of the Problem Based Learning Model position students as active participants who build understanding through problem investigation, discussion, and reflection. These conditions can foster curiosity, self-confidence, and the belief that they are capable of completing learning tasks. Learning motivation can arise from internal and external drives to engage in behaviors such as the desire to succeed, the need to learn, hopes and aspirations, and the rewards of learning (Nidawati, 2024).

The findings of this study are consistent with constructivist theory, which emphasizes that knowledge is actively constructed by learners through learning experiences. In the Problem Based Learning model, students do not merely passively receive information but play an active role in building their understanding through the process of inquiry and problem-solving. This process provides meaningful experiences that can enhance students' motivation to learn. This is consistent with the research by Faturrojad & Syahid (2024), which found that the application of the Problem Based Learning model is capable of stimulating students' motivation to learn.

The Effect of the Problem Based Learning model on acid-base learning outcomes

The results of the study show that the Problem Based Learning model has a significant effect on the learning outcomes of grade XI students of SMA Negeri 18 Makassar. This shows that the application of the Problem Based Learning model is able to increase the achievement of learning outcomes compared to educator-centered learning. The increase in learning outcomes occurs because the Problem Based Learning model puts students as active subjects who build understanding through problem investigation, discussion, and reflection students are given the opportunity to be actively involved in the learning process starting from students learning to express ideas/opinions, collaborating with groups, seeking information, asking questions/opinions and learning to communicate the results of discussions so that students are not passive in learning activities (Zahroh et al., 2023). So that the knowledge gained lasts longer in his memory.

The influence of the Problem Based Learning model can be seen in the three domains of learning outcomes, namely cognitive, affective, and psychomotor. In the cognitive realm, students who are taught using the Problem Based Learning model obtain better outcomes because they are actively involved in the process of finding concepts and solving problems. This involvement helps students develop a deeper understanding of the defense material.

In the affective realm, the Problem Based Learning model encourages students to show tolerance and caring, cooperation, communicative, responsibility, openness and criticism, discipline, and confidence during the learning process. The activity is student-centered and provides the opportunity to participate so that a positive attitude grows and develops in participating in learning activities. This is because students are involved in investigation activities, discussion processes, expressing opinions, and working together in groups to solve problems. So that higher involvement encourages the development of the affective aspect of students.

In the psychomotor realm, students have the opportunity to develop skills through various learning activities that require direct involvement in obtaining information or knowledge so that their skills are better. Thus, the application of the Problem Based Learning

model allows students to achieve better learning outcomes than when they only receive information and follow directions from educators. The results of this study are in line with the results of the research of Wagina et al. (2024) that the Problem Based Learning model can improve students' learning outcomes in cognitive, affective and psychomotor aspects.

The influence of learning style on acid-base learning motivation

The results of the study showed that learning style had a significant effect on the learning motivation of acid-base students in grade XI of SMA Negeri 18 Makassar. This indicates that students with different learning style characteristics show different learning motivations. This difference occurs because each student has a different tendency to receive, process, and understand information during the learning process.

Learning style is a combination of the way a person absorbs, organizes and processes information (Hernacki et al., 2004). In addition, learning style is also understood as an individualized approach to learning that affects the way students interact with their learning environment (Santrock, 2018). Students who gain learning experience according to their learning style tendencies are more likely to understand the material, feel comfortable in participating in learning activities, and show higher involvement. This condition can have an impact on increasing motivation to learn.

The difference in learning motivation between learning groups shows that internal factors also play a role in determining the success of the learning process. Therefore, education needs to consider the diversity of student characteristics in designing learning activities so that all students get optimal learning opportunities according to their characteristic needs. A child who has been motivated to learn something, that child will try to study well and be diligent in the hope of getting better results (Novianti et al., 2020). This is in line with the research of Putri et al. (2023) there is a relationship between learning styles and students' learning motivation.

The effect of learning style on acid-base learning outcomes

The results of the study showed that learning style had a significant effect on the learning outcomes of acid-base students in grade XI of SMA Negeri 18 Makassar. This indicates that there is a difference in the learning outcomes of acid-base students who have visual, auditory, and kinesthetic learning styles. These differences show that the way students receive, process, and understand information during the learning process also affects the achievement of learning outcomes. A person's tendency to learn varies, one of which is the use of appropriate learning styles will help students in the learning process so that students can easily absorb and understand the information received (Irawati et al., 2021).

The difference in learning outcomes can be seen in the three domains of learning outcomes, namely cognitive, affective, and psychomotor. In the cognitive realm, the characteristics of students' learning styles affect the way students understand concepts and process information. In the affective realm, differences in learning styles can be related to the level of involvement and response of students during learning. Meanwhile, in the psychomotor realm, different learning characteristics can be related to the ability of students to involve motor skills in carrying out learning activities. This is in line with Irawati et al. (2021) research that learning style makes a positive contribution to learning outcomes. Thus, the diversity of students needs to be a concern in the learning process. Educators need to provide various forms of activities and learning resources in order to accommodate the diverse learning needs of students so that students get the same opportunities to achieve optimal learning outcomes.

The effect of the interaction between the Problem Based Learning model and learning style on acid-base learning motivation

The results of the study showed that there was an interaction between the Problem Based Learning model and learning style on the acid-base learning motivation of grade XI students of SMA Negeri 18 Makassar. This shows that the influence of learning models and learning motivation is different on students who have different learning style characteristics.

Based on the results of the descriptive analysis, students with kinesthetic learning styles showed the highest learning motivation learned using the Problem Based Learning model. On the other hand, in the classroom taught using the direct learning model, the highest learning motivation was shown by students with auditory learning styles. These differences indicate that students respond differently to the learning experiences gained during the application of the Problem Based Learning model.

The interaction between Problem Based Learning and learning styles has a role because the Problem Based Learning model has a variety of different learning activities. Students with a visual learning style will find it easier to understand problems and concepts through visual media such as salt, graphics or illustrations. Students with an auditory learning style will be more motivated and understand the material when discussions, educator explanations, or presentations are used. Meanwhile, students with kinesthetic learning styles will be more effective in learning through practicum activities or direct demonstrations. The high motivation of students to learn with kinesthetic learning

styles in the Problem Based Learning model class provides opportunities for students to be actively involved in the learning process. Meanwhile, students with auditory learning styles show higher motivation in direct learning classes. This shows that the delivery of material through oral explanations, questions and answers, and directions from educators tends to be in accordance with the learning characteristics of the student group.

The compatibility between the Problem Based Learning model and the learning style of students can increase learning motivation. Learning motivation is an internal drive that affects how much students participate, focus, and try to understand the material (Woolfolk, 2016). When students feel that the way of learning is in accordance with their learning style, they are more active, enthusiastic and involved in the learning process so that their motivation to learn increases.

Thus, the results of this study show that the success of the application of the Problem Based Learning model in increasing learning motivation is not only influenced by the learning model used, but also related to the characteristics of students who follow the learning process. Therefore, educators need to pay attention to the diversity of student learning styles in designing learning activities so that all students can participate optimally. This is in line with the theory of visual, auditory, and kinesthetic learning styles which states that the compatibility between learning styles and learning strategies can increase students' engagement and motivation to learn (Simanungkalit et al., 2024).

The effect of the interaction between the Problem Based Learning model and learning style on acid-base learning outcomes

The results showed that there was an interaction between the Problem Based Learning model and learning style on the motivation and learning outcomes of grade XI students of SMA Negeri 18 Makassar. This shows that the achievement of learning outcomes of students is not only influenced by separate learning models or learning styles, but also the interaction of the two in the learning process.

Based on the results of descriptive analysis, the learning outcomes of students in each learning style group showed different tendencies in different learning models. This shows that the characteristics of students' learning styles are related to how to respond to the learning experience provided through a certain learning model. Thus, the learning outcomes achieved by students are influenced by the suitability between the learning characteristics and the learning characteristics they have.

In the Problem Based Learning model, students are actively involved in analyzing problems, developing arguments, and making decisions based on the data or concepts learned. This activity allows students to build an understanding of concepts through meaningful learning experiences. However, the involvement and use of these learning experiences can be different in each learning style group so that it results in different learning outcomes.

These differences are not only seen in the cognitive realm but also in the affective and psychomotor realms. In the cognitive realm, the interaction between learning models and learning styles is related to the way students understand and process information obtained during learning. In the affective realm, the interaction is reflected in the differences in attitudes, interests, and involvement of students in participating in learning. Meanwhile, in the psychomotor realm, the interaction is related to the ability of students to carry out learning activities and tasks that require skills.

This is in line with the results of Bakkara et al. (2025) research which states that the success of the implementation of the Problem Based Learning model is not only determined by the learning model used but also by the ability of educators to accommodate students' learning styles. Therefore, the application of the Problem Based Learning model is accompanied by a learning strategy that can accommodate various characteristics of learning styles so that all students get optimal opportunities to achieve maximum learning outcomes.

Conclusion

Based on the results of the data analysis and discussion, it can be concluded that the Problem Based Learning model has a significant effect on students' motivation and learning outcomes in acid-base topics. Learning styles also show a significant effect on students' learning motivation and learning outcomes in acid-base topics. In addition, there is an interaction between the Problem Based Learning model and learning styles on students' motivation and learning outcomes in acid-base topics.

Acknowledgments

The author would like to thank the supervisor who has provided direction and guidance during the research process and thesis preparation. The author also expressed his gratitude to the principal, staff and chemistry teachers at SMA Negeri 18 Makassar who have given permission and facilitated the conduct of the research.

Author Contributions

The author are contributors to this research, covering planning, data collection, data analysis, interpretation of results, and article writing.

Funding
This research was independently funded by the authors.

Conflicts of Interest
The authors declare no conflict of interest.

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