

IMPROVING SENIOR HIGH SCHOOL STUDENTS' CRITICAL THINKING SKILLS AND LEARNING ENGAGEMENT IN STOICHIOMETRY THROUGH PROBLEM- BASED LEARNING: A CLASSROOM ACTION RESEARCH

Azka Amalia¹, Fidia Lukita¹, Muryadi², and Setia Rahmawan^{1*}

¹Department of Chemistry Education, FTTE, UIN Sunan Kalijaga Yogyakarta

²SMA Muhammadiyah 7 Yogyakarta

e-mail: setia.rahmawan@uin-suka.ac.id

Abstract

Previous studies have shown that Problem-Based Learning (PBL) effectively improves students' critical thinking skills, learning outcomes, and engagement in stoichiometry. However, previous studies have mainly focused on learning outcomes. At the same time, the implementation of PBL through Classroom Action Research (CAR), which emphasizes continuous reflection and instructional improvement across cycles, has received limited attention. This study aimed to improve Grade 10 students' critical thinking skills and learning activities in stoichiometry by implementing the PBL model. This study employed the Classroom Action Research (CAR) method involving 20 Grade 10 students and was conducted in two cycles, each consisting of planning, implementation, observation, and reflection. The success criteria were determined based on improvements in students' critical thinking skills, learning activities, and learning mastery from Cycle I to Cycle II. Data were collected using pretests, posttests, student worksheets (LKPD), and observation sheets. The average posttest score increased from 82.50 in Cycle I to 85.25 in Cycle II, while student learning activities improved from 46.00% to 68.06%. The N-gain values were 0.254 in Cycle I and 0.175 in Cycle II, both categorized as low, indicating limited improvement due to students' relatively high initial achievement. In addition, learning mastery increased from 80% to 85%. These findings indicate that implementing the PBL model through continuous reflection and instructional improvement can enhance students' critical thinking skills and learning activities. Therefore, PBL can serve as an effective instructional strategy for chemistry teachers to promote active learning and foster students' critical thinking skills in stoichiometry.

Keywords: classroom action research, problem-based learning, critical thinking, stoichiometry

INTRODUCTION

Critical thinking is an essential skill students need in 21st-century learning and an increasingly necessary competency in the era of the Fourth Industrial Revolution [1,2]. Critical thinking is the ability students use to formulate and identify problems, pinpoint the core of an issue, determine similarities and differences, extract relevant information and data, and evaluate and reflect on facts and data [3,4]. This skill is particularly important in science education—including chemistry—as it helps students understand abstract concepts, analyze data accurately, and solve scientific problems systematically [5,6]. Furthermore, mastering critical thinking skills in chemistry not only improves learning outcomes but also helps students develop a deeper conceptual

understanding, enabling them to connect chemical concepts to the resolution of real-life scientific problems [7].

One of the subtopics in chemistry that requires critical thinking in the learning process is stoichiometry. The high school-level material on stoichiometry is considered difficult for most students, particularly the mole concept [8]. Stoichiometry is one of the fundamental topics in high school chemistry and serves as the foundation for understanding higher-level chemistry concepts. However, in practice, stoichiometry is still considered difficult by most students, particularly the concept of the mole, as it requires not only the ability to perform mathematical calculations but also an understanding of the mole concept, the ability to interpret chemical equations, and the

ability to connect various chemical concepts to solve problems systematically [9]. International research also indicates that stoichiometry is one of the most fundamental competencies in chemistry education, as it is a prerequisite for understanding advanced chemical concepts. However, many students still learn stoichiometry procedurally through calculation algorithms without understanding the conceptual meaning behind the chemical processes that occur [10]. Therefore, a learning model is needed that can address students' challenges and difficulties. One learning model that can enhance student engagement and critical thinking skills is Problem-Based Learning (PBL) [3].

The PBL model is a student-centered learning model that uses contextual problems to develop thinking and problem-solving skills [4]. In this model, students are encouraged to identify problems, analyze information, engage in discussions, and develop solutions based on the concepts they have learned. These characteristics make PBL suitable for application to stoichiometry material because learning requires not only calculation skills but also the ability to understand concepts and determine logical problem-solving strategies. This aligns with findings from various systematic reviews, which show that PBL fosters a more student-centered learning experience through active engagement in inquiry, discussion, and problem-solving, thereby improving critical thinking skills, learning outcomes, and student engagement in chemistry education [11]. These findings are also supported by various studies reporting that PBL effectively enhances critical thinking skills across various chemistry topics, such as hydrocarbons and stoichiometry [12,13,14]. In addition to enhancing cognitive aspects, PBL also encourages students to be more active in discussing, asking questions, expressing opinions, and collaborating to solve problems, thereby increasing student engagement during learning [15,16].

Although various studies have demonstrated the effectiveness of PBL in enhancing critical thinking skills and learning engagement, most employed quasi-experimental designs or were conducted with subjects other than stoichiometry.

Research examining the application of PBL through Classroom Action Research on stoichiometry, specifically to improve critical thinking skills and learning engagement simultaneously, remains relatively limited. Therefore, this study was conducted to examine the effect of implementing Problem-Based Learning (PBL) through Classroom Action Research on improving students' critical thinking skills and learning engagement in basic stoichiometry. In line with this, the study aims to improve students' critical thinking skills and learning engagement by implementing the Problem-Based Learning (PBL) model in basic stoichiometry at SMA Muhammadiyah 7 Yogyakarta.

METHOD

This study employed the CAR (Classroom Action Research) method with 20 Grade 10 students from SMA Muhammadiyah 7 Yogyakarta. The study was conducted in 2 cycles. The students were selected because preliminary discussions with the chemistry teacher indicated that they had difficulties in understanding stoichiometry concepts. Each cycle comprised four interrelated stages: planning, implementation, observation, and reflection. To ensure consistency in evaluating students' critical thinking abilities, the same pretest and posttest assessments were used in both instructional cycles. These assessments were administered after the learning activities in each cycle to minimize recall bias. In Cycle II, Google Forms was utilized, with the question shuffle feature activated, providing each student with a unique sequence of questions. To maintain the validity of the evaluation results, students completed the tests independently while under teacher supervision. Subsequently, observations were conducted to evaluate the learning process and outcomes, followed by reflection to identify instructional deficiencies. Findings from the cycle I reflection served as the foundation for corrective improvements in cycle II. Cycle II was executed using the identical four-phase framework planning, implementation, observation, and reflection ultimately yielding improvements in students' critical thinking skills

and conceptual understanding presented in Figure 1.

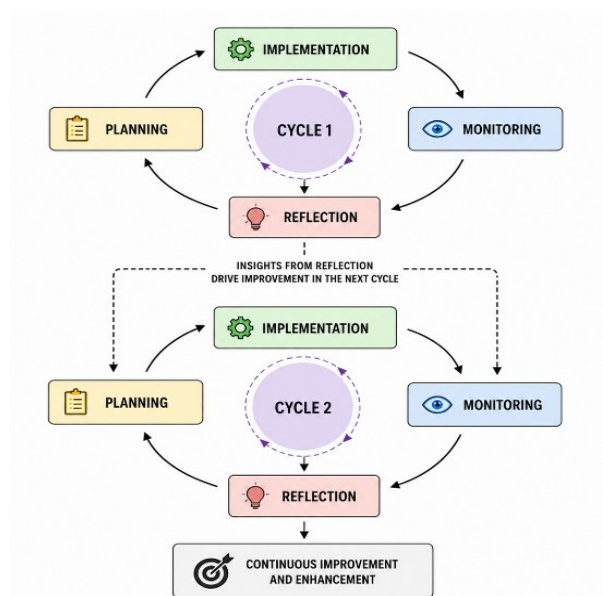


Figure 1. Classroom Action Research Procedure

The explanation of the research flow is as follows:

Cycle I

a. Planning

At this stage, the researcher creates a design regarding the focus of the problem to be researched, which includes:

- 1) Compiling teaching modules and lesson plans on stoichiometry material.
- 2) Prepare research instruments for students.
- 3) Prepare stoichiometry lesson materials in PowerPoint format.

b. Implementation

- 1) Researchers gave pretest questions at the beginning of the lesson.
- 2) Researchers began learning by providing apperception to direct students to the learning material.
- 3) The teacher explained the learning objectives to improve learning outcomes.
- 4) Researchers carried out the planned sequence of activities using the Problem-Based Learning (PBL) method.
- 5) During the learning process, students engaged in group discussion activities to complete the LKPD.
- 6) The researcher gave posttest questions at the end of the lesson.

c. Observation

The implementation of the Problem-Based Learning (PBL) model was evaluated through classroom observations of student participation during the learning process using observation instruments developed by the researcher. One member of the research team conducted classroom observations, while another researcher implemented the learning activities. Before data collection, the observer discussed the observation indicators and scoring rubric with the research team to ensure a consistent understanding of the assessment criteria. Since a single observer conducted classroom observations, inter-rater agreement was not applicable in this study. These observations were conducted to assess the extent of student engagement in instructional activities. In addition, students' critical thinking skills were measured using data obtained from pretest and posttest assessments, as well as their performance on student worksheets (LKPD) completed throughout the learning activities.

d. Reflection

Researchers reflect on learning outcomes after learning is complete.

Cycle II

The stages in cycle II are the same as the series of activities carried out in cycle I. Several learning methods are carried out differently at the implementation stage, namely:

- 1) At the start of learning, the researcher refreshed the material from cycle I by conducting a question-and-answer session.
- 2) Before the material began, the researcher gave pretest questions.
- 3) The researcher reexplained the learning objectives to improve the learning outcomes to be achieved.
- 4) Students worked on questions in front of the class to develop learning activities that increase student engagement and participation during the learning process.
- 5) The researcher gave a posttest at the end of the lesson.
- 6) Before closing, the researcher refreshed the learning material with the students.

The following is a descriptive explanation of each research instrument.

1) Data collection technique

Data collection techniques in this study include pretest questions, posttest questions, LKPD questions, and observation sheets of student activity during learning.

a) Pretest and posttest instruments were used to assess students' critical thinking abilities before and after the intervention. The assessment comprised five descriptive questions on stoichiometry, covering the concepts of relative atomic mass (A_r), relative molecular mass (M_r), and the mole concept, as presented in Table 1.

Table 1. Pretest and Posttest Question Grid

No.	Question Grid
1.	Calculation of Relative Atomic Mass (A_r) and Relative Molecular Mass (M_r)
2.	Calculation of the Number of Moles from the Mass of a Substance
3.	Calculating the number of moles based on the number of particles
4.	Calculate the number of moles of gas at STP conditions based on the volume of gas
5.	Determining the mole ratio of reactants based on the reaction coefficient
6.	Determine the number of moles of substances that react based on the balanced reaction equation

The assessment of students' critical thinking skills is based on a rubric comprising accuracy in (1) writing the correct formula, (2) substituting numbers correctly, (3) performing the calculation process correctly, and (4) stating the final result and units correctly, as presented in Table 2.

Table 2. Pretest and Posttest Assessment Rubric

No.	Rated aspect	Score
1.	Writing the correct formula	5
2.	substituting numbers correctly	5

No.	Rated aspect	Score
3.	Performing the calculation process correctly	5
4.	Stating the final result and units correctly	5
Total		20

Each assessment criterion was assigned an equal score of 5 points because all four aspects were considered equally important for representing students' critical thinking during stoichiometric problem-solving. Therefore, each question had a maximum score of 20 points, and the total score for the five questions was 100 points. The chemistry subject teacher validated the pretest and posttest instruments to ensure the suitability of the material, question indicators, and learning objectives.

- b) Student Worksheets (LKPD), Student worksheets (LKPD) were utilized as instructional tools to facilitate students' understanding of the learning material through discussion and problem-solving activities. In addition, the worksheets served as an assessment instrument to evaluate students' abilities to analyze and solve the problems presented during the learning process.
- c) Student Activity Observation Sheet, was used to observe student activity during the learning process. The observed indicators are shown in Table 3.

Table 3. Student Activity Indicators

No.	Indicator
1.	Questioning behavior
2.	Responding to inquiries
3.	Attentiveness during teacher explanations
4.	Completion of the worksheets (LKPD)
5.	Reflecting on learning

Each indicator is scored from 1 to 3, with 1 = inactive, 2 = moderately active, and 3 = active. The percentage of student activity is then categorized as follows in Table 4.

Table 4. Student Response Criteria

Percentage (%)	Criteria
0-20	Very weak
21-40	Weak
41-60	Fair
61-80	Strong
81-100	Very strong

[17]

The success indicators for this Classroom Action Research (CAR) were determined by improvements in students' critical thinking skills and learning activities. The study was considered successful if the average posttest score increased from Cycle I to Cycle II and students' learning activities reached the Strong (61–80%) or Very Strong (81–100%) category, as indicated by the observation results.

2) Data Analysis Techniques

The data obtained were analyzed descriptively. Students' critical thinking skills were analyzed by comparing the average pretest and posttest scores for each cycle. To determine the improvement in students' critical thinking skills following the implementation of the Problem-Based Learning (PBL) model, calculations were performed using normalized gain (N-gain) based on the formula:

$$N - Gain = \frac{skor\ posttest - skor\ pretest}{skor\ maksimum - skor\ pretest}$$

With the following N-Gain categories presented in Table 5.

Table 5. N-Gain Category

N-Gain	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Fair
$g < 0.3$	Low

3) Ethical Considerations

This study was conducted after obtaining permission from the university, the principal of SMA Muhammadiyah 7 Yogyakarta, and the chemistry teacher. The entire research process complied with the school's regulations, and all data collected

were used solely for research purposes while maintaining the confidentiality of the students' identities.

RESULTS AND DISCUSSION

This classroom action research was conducted over two cycles, each comprising four sequential stages: planning, implementation, observation, and reflection [18]. The study focused on stoichiometry content utilizing the Problem-Based Learning (PBL) model as an intervention to enhance students' critical thinking skills. Each cycle was implemented within a single meeting session, with corrective measures refined based on the reflective findings from the preceding cycle. According to the learning implementation data, students' learning outcomes demonstrated progressive improvement across both cycles. This enhancement is evident in the comparison of mean pretest and posttest scores, as illustrated in the Figure 2.

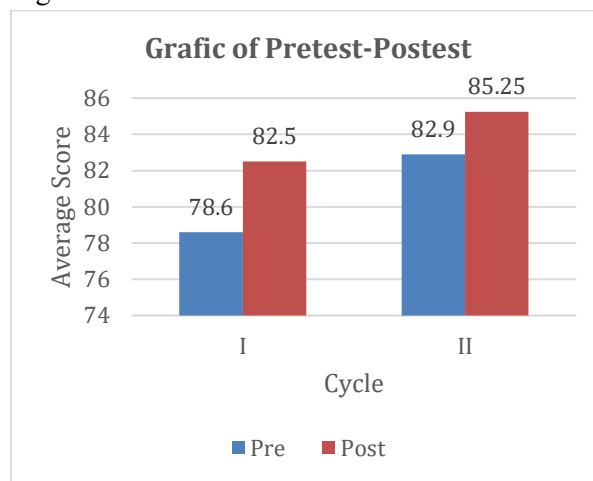


Figure 2. Comparison of Pretest-Posttest Scores

Figure 2 compares average pretest and posttest scores for students in Cycles I and II. The x-axis shows the research cycles, while the y-axis shows the average student scores from the assessments. The blue bars indicate mean pretest scores, and the orange bars represent mean posttest scores for each cycle.

The comparison of pretest and posttest results across Cycles I and II revealed a consistent improvement in students' learning outcomes throughout the learning process. The mean posttest score increased from 82.5 in Cycle I to 85.25 in Cycle II. The results suggest that implementing the

Problem-Based Learning (PBL) model positively affects students' achievement in stoichiometry. Although the improvement was relatively small, the results indicate that students' conceptual understanding developed through the problem-solving process during the learning activity. The improvement in students' critical thinking skills was determined using the N-gain analysis. The results are presented in Table 6.

Table 6. N-Gain Analysis of Students' Critical Thinking Test Scores

Cycle	Mean Score		N-Gain	Category
	Pre	Post		
Cycle I	78,6	84,025	0,25	Low
Cycle II	82,9	85,25	0,13	Low

Although the increase in the average final exam score from Cycle I to Cycle II was relatively small, these results indicate progress in students' conceptual understanding of stoichiometry. From an educational perspective, these findings suggest that implementing Problem-Based Learning (PBL) provides students with opportunities to construct knowledge through problem-solving, discussion, and conceptual exploration. Thus, learning is not only oriented toward achieving high scores but also toward developing a more meaningful understanding of stoichiometry concepts. Moreover, the apparent enhancement could be explained by the successful application of the PBL approach, which was associated with improvements in classroom learning activities. The stoichiometric approach is especially well-suited to implementing the Problem-Based Learning (PBL) model, as the topic requires students to use analytical skills, mathematical reasoning, and problem-solving strategies. Rather than memorizing formulas, students are guided to develop a holistic understanding of the principles and calculation methods of stoichiometry through problem-centered learning experiences [14].

Based on Table 5, the N-gain value in Cycle I was 0.254 and was categorized as low. Similarly, the N-gain value in Cycle II was 0.175, which also fell into the low category. Although the N-gain value decreased in Cycle II, this finding does not indicate that the implementation of the Problem-Based Learning (PBL) model became less effective. The lower N-gain values can be

explained by the higher pretest scores in Cycle II, which reduced the potential for further improvement toward the maximum score. Consequently, although the relative improvement in student scores was smaller, the increase in the average posttest score and learning achievement indicates that the implementation of PBL continues to make a positive contribution to students' critical thinking skills. This finding is consistent with the characteristics of the normalized gain index, which accounts for the maximum potential improvement based on students' initial scores [19].

Statistical analysis to examine differences between Cycle I and Cycle II was not conducted because this study employed a classroom action research design that focused on continuous improvement of the learning process rather than hypothesis testing between cycles. Furthermore, the same students participated in both cycles, and Cycle II represented an improvement of the instructional intervention implemented in Cycle I. Therefore, a descriptive analysis of score progression and mastery of learning was deemed sufficient to evaluate the intervention's effectiveness, as illustrated in the Figure 3.

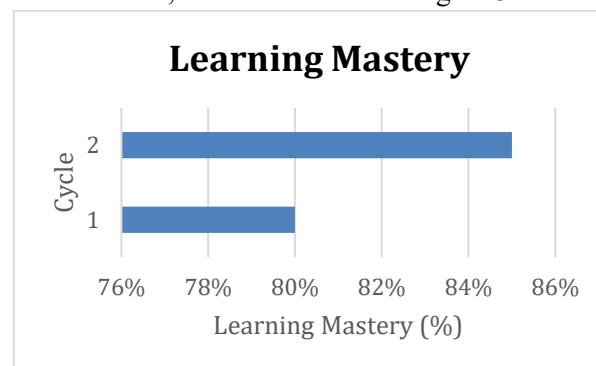


Figure 3. Comparison of Learning Mastery

According to Figure 3, the percentage of students who achieved learning mastery increased from 80% in Cycle I to 85% in Cycle II. The improvement shows that applying the Problem-Based Learning (PBL) model, with improvements in instruction in Cycle II, positively impacts students' achievement of the minimum mastery criteria. The increase in the average posttest score is in line with the improvement in learning mastery. This shows that more students can understand and apply the concepts of stoichiometry well after problem-based learning activities. Although the

improvement in learning mastery was relatively small, the results indicate a positive trend in students' academic achievement. The use of contextual problem-solving activities, group discussions, and interactive quizzes encouraged students to engage more actively in the learning process, thereby improving their understanding of stoichiometry concepts and problem-solving skills.

Cycle I

a) Planning

The Problem-Based Learning (PBL) model has been documented to enhance students' critical thinking skills and learning engagement, as learners are actively involved in the Problem-solving process [20]. The instructional tools developed for this research included teaching modules, problem-based student worksheets (LKPD), pretest and posttest instruments, student activity observation sheets, and critical-thinking assessment rubrics. The pretest was administered to assess students' prior knowledge before instruction, whereas the posttest was utilized to evaluate improvements in students' critical thinking abilities following the intervention [21].

The student worksheets (LKPD) were developed following the Problem-Based Learning (PBL) framework, incorporating authentic, contextualized problems aligned with stoichiometry content. Also, the researchers developed observation protocols for monitoring student engagement that included the following dimensions: questioning behavior, responding to inquiries, attentiveness during teacher explanations, completion of the LKPD, and reflective practice. The planning phase was conducted to ensure the instructional process proceeded systematically and aligned with the research objective, which aimed to enhance students' critical thinking skills through the implementation of the PBL model.

b) Implementation

The implementation of Cycle I actions began with a pretest to assess students' initial understanding of stoichiometry. Next, the teacher presented the material and divided students into groups to work on Problem-Based

Learning (PBL)-based worksheets containing contextual problems. During the discussion, the teacher guided students in analyzing and solving the problems. Students participated in guided group discussions while completing the student worksheet activities in Cycle 1. The learning process is illustrated in Figure 4.



Figure 4. Guided group discussion of LKPD Cycle 1

Students' critical thinking skills were assessed through their answers to the student worksheet (LKPD) and posttest questions. At the end of the lesson, students were given a posttest to determine their improvement in critical thinking skills after implementing the Problem-Based Learning model. The application of Problem-Based Learning to stoichiometry can help students understand concepts through contextual problem-solving and discussion groups [22].

c) Observation

The observation phase was conducted throughout the instructional implementation using a pre-designed student activity observation sheet. The observational findings revealed that several challenges persisted throughout the learning process, including instances of student noise and inattentiveness during teacher explanations. Furthermore, not all students were actively engaged in group discussions or in completing the worksheets, as some continued to rely on their groupmates to complete the assigned questions. Additionally, several students expressed concern that the activities in a single meeting were excessively demanding, as they were required to complete the pretest, worksheet discussion, and posttest in the same session. The results of the observations are presented in Table 7.

Table 7. Results of Observations of Student Activities in Cycle I

No.	Indicator	Percentage	Category
1.	Questioning behavior	50%	Fair
2.	Responding to inquiries explanations	56.94%	Fair
3.	Attentiveness during teacher explanations	59.72%	Fair
4.	Completion of the worksheets	62.50%	Strong
5.	Reflecting on learning	1%	Very Weak

Based on the observation results of student activities, the indicator of working on LKPD had the highest percentage, at 62.50%, and was in the strong category. In contrast, the indicator of reflecting on learning had the lowest percentage, at 0%, and was in the very weak category. This indicates that students are quite active during learning, but still lack reflection on learning. Nevertheless, the application of the Problem-Based Learning (PBL) model in cycle I improved student learning outcomes, as indicated by an increase in the average posttest score from 78.6 to 82.5.

These findings indicate that the Problem-Based Learning (PBL) model effectively facilitates students' comprehension of stoichiometry through active engagement in problem-solving tasks and collaborative group discussions [22]. The results of the present investigation are consistent with prior research by Zhahra, which reported that implementing the PBL model positively influences both students' learning engagement and their critical thinking competencies in chemistry education. These empirical findings further substantiate PBL's potential as an effective pedagogical approach for fostering active learning and higher-order thinking skills [23].

d) Reflection

The results of implementation and cycle I showed that the Problem-Based Learning model improved students' critical thinking. However, the implementation still needs improvement to make the learning process more

effective and involve students more in the learning activities. The main challenges typical of cycle I were the following: students were not attentive during lessons, did not actively participate in group discussions, and there were too many tasks to complete in a single session. Furthermore, it was discovered that some students used the internet or GPT to complete the pretest and posttest questions, leading to scores that did not accurately reflect students' critical thinking abilities. Consequently, the researcher devised multiple enhancements for the upcoming cycle. The improvements that will be made in cycle II are:

1. The teacher asks questions at the beginning of the lesson to review prior material, helping students better prepare to follow along.
2. Teachers give simple rewards or gifts to students who actively ask, answer, and discuss, thereby increasing students' motivation to learn.
3. In cycle I, the LKPD was changed to an interactive quiz activity to encourage students to be more active, enthusiastic, and interested during the learning process.
4. The pretest and posttest, originally paper-based, were moved to Google Forms and set so that students cannot copy-paste or switch screens while working on the questions, thereby better reflecting students' critical thinking abilities

Cycle II

a) Planning

Cycle II was implemented as an improvement on Cycle I. In the planning stage, the researcher made several improvements based on reflections on the previous cycle. The pretest and posttest, which were originally paper-based, were converted to Google Forms configured to prevent students from switching screens while working on the questions. In addition, the Student Worksheet (LKPD) used in Cycle I was replaced with an interactive quiz to increase student activity and enthusiasm during the learning process [24]. Researchers also prepared rewards for students who actively

asked and answered questions during the lesson.

b) Implementation

The actions in cycle II were implemented in a single meeting using the Problem-Based Learning (PBL) model for the stoichiometry material. The learning activity began with a pretest in Google Forms to assess students' initial abilities. Next, the teacher addressed issues with the learning material and guided students through the interactive quiz activity. During the learning process, students appeared more active and enthusiastic compared to cycle I. This was evident in students' enthusiasm as they raised their hands when the teacher presented the quiz questions. At the end of the learning process, students were given a posttest to assess their learning outcomes.

c) Observation

Based on Figure 2, it can be seen that, across cycles I and II, student learning outcomes increased from the pretest to the posttest. The results show that using the Problem-Based Learning (PBL) model, supported by enhanced learning activities, can help students better understand stoichiometry and solve assigned problems. The PBL model aligns with the characteristics of stoichiometry, a subject that requires analytical skills, problem-solving, and mathematical reasoning. Students are expected to memorize formulas for solving stoichiometry problems; however, they are also expected to understand the concepts of moles, reaction equations, and the correct steps for calculations. Thus, problem-based learning helps students better understand stoichiometry. In addition to improving critical thinking skills, implementing learning activities in Cycle II was associated with higher student engagement throughout the instructional process. Using Google Forms created a more structured assessment environment, enabling students to concentrate more effectively during the pretest and posttest sessions by minimizing distractions from other applications. Moreover, integrating interactive quizzes increased student participation and enthusiasm, resulting in a

more interactive and engaging learning experience.

Increased learning activities during the learning process are also believed to be related to improved student learning outcomes [25]. Through group discussions, problem-solving, and learning quizzes, students become more active in developing their understanding of stoichiometry. The results of the post-tests suggest that active student engagement in learning gives them more opportunities to discuss problems, share opinions, and assess solutions, thereby enhancing learning outcomes. In addition to improving critical thinking skills, implementing learning in cycle II also increases student activity during the learning process. Google Forms keeps students focused and orderly during pre-test and post-test because they cannot open other applications while answering the questions. Also, the interactive quiz helps students be more active and enthusiastic in the learning process.

According to Table 6, all indicators of student learning activities increased in cycle II compared to cycle I. The percentage of asking questions remained the lowest among the indicators, but increased compared to cycle I. Meanwhile, the highest percentage was for the task completion indicator, since students were more active and enthusiastic during the quiz. Although all indicators of learning activity showed improvement, the reflection indicator still demonstrated relatively lower achievement compared to the other indicators. This is evident from the fact that only two students were willing to share their reflections in Cycle II, whereas in Cycle I, no students shared their reflections. This situation is likely due to the students not yet being accustomed to evaluating their thought processes or learning outcomes.

Additionally, in previous chemistry lessons, learning activities were generally concluded by the teacher without involving students in reflection activities, so they still feel uncomfortable expressing their opinions or learning experiences. This study was also conducted over only two cycles, with one session per cycle; thus, the available time was

insufficient to establish a sustained habit of reflection. This finding is consistent with Mohamed et al., who state that reflective ability develops through a repetitive process and requires ongoing opportunities to evaluate learning experiences [26]. Therefore, if the study were conducted over a greater number of cycles or a longer period, the students' reflective abilities would likely develop more optimally.

The increase in these two indicators shows that the Problem-Based Learning model can train students to solve problems and enhance their higher-order thinking skills [27]. Furthermore, when students are given an active role in the learning process, they are more likely to ask questions, think critically, and respond to teacher questions. This activity aligns with the goals of learning stoichiometry, which require logical understanding and analytical thinking [16]. The findings of this study are consistent with constructivist theory, which states that knowledge is actively constructed through learning experiences, discussions, and problem-solving [28]. This was reflected during the implementation of PBL in Cycle II, where

students had the opportunity to develop their understanding by solving contextual problems in an interactive quiz, so that they not only memorized concepts but also applied them to solve stoichiometry problems. This activity also reflects the principle of active learning because students were actively engaged in answering questions, analyzing problem-solving approaches, and providing feedback on the answers that appeared during the quiz. This process supports the development of critical thinking skills because students were required to analyze information, select appropriate problem-solving strategies, and evaluate the results obtained [29].

The findings of this study align with Melani's [30] investigation, which shows that the implementation of the Problem-Based Learning (PBL) model can improve students' engagement and learning outcomes, as well as the research by Priska et al. [31], which indicates that PBL can enhance students' critical thinking skills. The comparison of student learning activities in Cycle I and Cycle II is presented in Table 8.

Table 8. Comparison of Student Learning Activities in Cycle I and Cycle II

No.	Indicator	Cycle 1	Cycle 2
1.	Students dare to ask the teacher during the learning process	50%	66.67%
2.	Students dare to answer questions from the teacher.	56.94%	69.4%
3.	Students pay attention to the teacher	59.72%	77.78%
4.	Students work on LKPD	62.5%	86.1%
5.	Students dare to reflect on learning	1%	40.28%
Average		46	68.06

d) Reflection

Based on the results of cycle II implementation, the learning process was more conducive than in cycle I. Students appeared more active, focused, and enthusiastic during the learning process. Improvements, such as using Google Forms, interactive quizzes, and rewards, positively influenced students' critical thinking skills. Therefore, the classroom action research was stopped in cycle II because the indicators of research success had been achieved. The PBL method was also effective.

Although the study's success indicators have been met, this research still has several limitations. The study involved only one class with two cycles of intervention, so the available time was insufficient to fully optimize improvements in students' learning engagement and reflective skills. Additionally, this study focused solely on basic stoichiometry, so the results cannot yet illustrate the effectiveness of the Problem-Based Learning model in other chemistry topics. Therefore, future research is recommended to conduct the intervention over

a greater number of cycles, involve a larger number of students, and test the application of the Problem-Based Learning model to other chemistry topics. Future research could also examine other variables, such as problem-solving skills, learning motivation, or concept retention, to provide a more comprehensive picture of the effectiveness of this learning model.

CONCLUSION

The implementation of the Problem-Based Learning (PBL) model in teaching basic stoichiometry has been shown to improve students' critical thinking skills, learning outcomes, and learning engagement. These findings indicate that problem-based learning provides students with the opportunity to build conceptual understanding through problem-solving activities, thereby making the learning process more active and meaningful. However, the increase in student engagement remains relatively limited, indicating that developing active learning habits requires time and sustained implementation of this approach. Therefore, the Problem-Based Learning model can serve as an alternative teaching method that chemistry teachers can adopt to develop students' critical thinking skills while simultaneously enhancing their engagement in stoichiometry instruction.

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