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The Influence of the Flipped Classroom Based on the Problem-Based Learning Model on the Material of Reaction Rate on Students' Problem-Solving Abilities

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Abstract: Problem-solving ability is one of the skills that must be possessed in the 21st century. Problem-solving ability needs to be possessed by students to overcome problems in everyday life and academically. This study aims to analyze the significant differences in students' problem-solving ability on the reaction rate material between students who use flipped classroom learning based on problem-based learning and those who use scientific learning. This type of research is a quasi-experiment with a pretest-posttest control group design. The population in this study was a state high school in West Yogyakarta. The sampling technique used was random sampling of the class. The sample used in this study consisted of two classes, namely the experimental class and the control class. The experimental class used flipped classroom learning based on problem-based learning, while the control class used learning with a scientific approach. Data were obtained through problem-solving ability test instruments in the form of pretests and posttests. The test instruments used were validated theoretically and empirically. Indicators of problem-solving ability measured in the pretest and posttest include understanding the problem, preparing a problem-solving plan, implementing the problem-solving plan, and rechecking the results of the problem-solving. Based on the results of the t-test significance analysis of 0.000 < 0.005, it shows that there is a significant difference in problem-solving ability between students who use flipped classroom learning based on problem-based learning and those who use a scientific approach. Flipped classroom learning based on problem-based learning is one of the innovative learning methods to improve students' problem-solving abilities.

Keywords: flipped classroom, problem-based learning, problem-solving ability, reaction rate.

▪ INTRODUCTION

The development of science and technology in the 21st century is growing very rapidly. One of the 21st-century skills that needs to be developed is problem solving (Paristiowati et al., 2019). 21st-century education emphasizes students' ability to formulate problems, think critically, be creative, and collaborate with others to solve problems (Sholihah & Lastariwati, 2020). Problem-solving skills need to be possessed by students to overcome problems in everyday life and academics (Rachmantika & Wardono, 2019). In life, some problems cannot be avoided, so they require the ability to solve them (Purwaningsih et al., 2020; Dostál, 2015). Problem solving is an activity that requires adequate knowledge, abilities, and cognitive methods as well as approaches in the problem-solving process (Mahanal et al., 2022). An important element in problem solving is finding and implementing the most appropriate strategy to solve the problem at hand (Yilmaz, 2022; Barriyah, 2021; Rosdianaa et al., 2019).

However, this problem-solving ability is often not optimally developed in students. This is in line with several previous studies: Low problem-solving abilities of students are influenced by a lack of initial knowledge and conceptual understanding, so that they are unable to connect the concepts underlying the problem. Students do not think about the right steps to solve a problem (Ijirana et al., 2020). Low problem-solving abilities are also influenced by the learning steps used, which tend not to hone students' high-level

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thinking skills. Teachers are more active in explaining so that communication only occurs in one direction, and students only note down the material given by the teacher (Mardiansyah et al., 2022). Teachers, teaching and learning activities do not give students effective problem-solving exercises, are less varied, and the teacher's teaching style makes students have difficulty solving problems (Rohayah, 2022).

One of the innovative learning methods that can be used is the flipped classroom. The flipped classroom is a learning method that is reversed from traditional learning. Flipped classroom learning is more student-oriented (Atkinson et al., 2020). Learning with the flipped classroom method allows students to learn concepts before coming to class. Students can watch and read using mobile devices anywhere, offering flexibility and opportunities for independent learning (Jr et al., 2023). The method of delivering content outside of class can vary, namely tutorials, readings, videos, podcasts, video recordings of lectures, etc. (Fautch, 2015). During face-to-face meetings in class, students will do problem-solving and active learning (Pulukuri & Abrams, 2021). Shell and Mazur's research on the flipped classroom shows the importance of providing a place to learn outside of scheduled class times (Schell & Mazur, 2015).

In addition to using the flipped classroom method, a problem-based learning approach is also used, which functions as another alternative that aims to improve problem-solving skills. In this model, students face real and relevant challenges that they face in everyday life (Mataka & Kowalske, 2015). Problem-based learning focuses on utilizing issues to develop problem-solving skills, knowledge, and applicable regulations (Eggen & Kauchak, 2012). This educational approach encourages the development of strategies to overcome problems during the learning journey. In addition, problem-based learning as a model equips students with the knowledge, competencies, and values that are important to effectively address the demands of the 21st century (Ee et al., 2023).

Therefore, the flipped classroom approach can be integrated with other learning frameworks, especially the problem-based learning (PBL) model. The combination of flipped classroom techniques with problem-based learning creates a synergistic effect that can improve learning outcomes while encouraging students to be more actively involved and student-centered in learning. Before attending class, students can study the material first, which will better equip them to participate in discussions and activities (Ranga, 2020). The flipped classroom method combined with problem-based learning seeks to transform passive learning into active engagement by engaging students in problem-solving tasks through reflective action and practice (McGrath et al., 2017). Research conducted by Paristyowati et al. (2019) showed that the combination of flipped classroom and problem-based learning strategies resulted in better outcomes related to deeper understanding, increased student motivation, higher levels of student participation, and increased teacher-student interaction. Similarly, the study by Sinmas et al. (2019), which implemented the problem-based learning model in conjunction with the flipped classroom method, revealed significant differences in learning achievements between students engaged with the problem-based learning (PBL) framework and those exposed to traditional instructional methods. However, both studies examined students' understanding and learning achievement. In Indonesia, there is still little research on flipped-PBL to improve problem-solving skills, so researchers are interested in seeing the effect of flipped-PBL learning on students' problem-solving skills.

Based on the description above, this study aims to determine the effect of flipped classroom learning based on problem-based learning on students' problem-solving abilities. The hypothesis is that there is a significant difference in problem-solving abilities between students who take flipped classroom learning based on problem-based learning and students who take scientific learning.

▪ METHOD

Participants

This study was carried out at SMA Negeri 4 Yogyakarta during the odd semester of the 2024/2025 academic year, focusing on class XI. The population for this research consisted of SMA Negeri schools in West Yogyakarta, amounting to a total of five institutions: SMA Negeri 1, 2, 4, 7, and 10. From these five schools, one institution was randomly chosen, specifically class XI of SMA Negeri 4 Yogyakarta, which includes four classes. Each class comprises 36 students, resulting in an overall student count of 144. To determine the two classes that would function as the control and experimental groups, the researcher performed normality and homogeneity tests using the daily test scores from the previous material for class XI students. The normality test results for classes F1, F4, F5, and F6 were recorded as 0.276, 0.675, 0.502, and 0.056, respectively. These findings indicate that the data is normally distributed since the significance values are greater than 0.05. The homogeneity test yielded a result of 0.053, also indicating a significance value exceeding 0.05; thus, it can be concluded that the data stems from a homogeneous population. The analysis results demonstrate that all classes possess initial equivalence, allowing for random selection among them.

Research Design and Procedures

This study is a study that uses a quantitative approach with a quasi-experimental method. The research design used is a pretest-posttest control group. This study used two classes, namely the experimental class and the control class. Both classes were given different treatments. In the experimental class, flipped classroom learning was carried out based on problem-based learning, and in the control class, a scientific approach was used. The experimental class and control class were given a pretest at the beginning of learning and a posttest at the end of learning. This study consisted of 6 meetings, starting with a pretest; in the second meeting, students learned about the concept of reaction rate; the third meeting was the reaction rate equation and reaction order, the fourth meeting was the collision theory, the fifth meeting was the factors that affect the reaction rate, and it ended with a posttest to determine the data on problem-solving abilities.

In the experimental class, the flipped classroom method has three stages, namely pre-class, in-class, and post-class. In the pre-class stage, students watch learning videos, work on questions based on the videos that have been watched, and make notes before learning in class. Before learning, the teacher will check the notes that students have made. In learning in class, students carry out five stages of learning according to the problem-based learning model, including student orientation to the problem, organizing study groups, guiding independent and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. The five stages of learning are carried out with the help of LKPD, which has been prepared according to the problem-based learning model, and is carried out in groups. At the end of learning, the teacher and students review the material that has been studied. The flipped classroom activities of students after class are understanding the material that has been given and preparing themselves for the next material.

In the control class, learning uses a scientific approach, so it is different from the experimental class; students will learn the material at school. In the preliminary activity, the teacher checks attendance and gives greetings, apperception, and motivation. In the core activity, students will carry out five stages of learning with a scientific approach, including observing, asking, collecting data, associating, and communicating. In learning, students will use scientific learning LKPD, which is carried out in groups. In the closing activity, the teacher and students conclude the material that has been studied; students are asked to restudy the material that has been studied.

The research flow carried out by the researcher is as follows: (1) Interviews with chemistry teachers and 3 students who have received material on reaction rates, (2) preparing data collection instruments, (3) validating problem-solving ability test instruments, (4) pretests related to problem-solving abilities before treatment, (5) implementing learning activities using LKPD, (6) posttests related to problem-solving abilities after treatment, (7) analysis of the data obtained.

Instrument

The data collection instruments in this study were interview guidelines and problem-solving ability test sheets. The interviews conducted in this study used unstructured interviews. Interviews were conducted to determine the characteristics, learning models, and abilities of students. Problem-solving ability tests were conducted at the beginning (pretest) and end (posttest) of learning activities. The questions to be used in the study were validated theoretically and empirically. Theoretical validity was carried out by 2 expert lecturers with results that were suitable for use. Questions that had been validated based on theoretical validity were then continued with empirical validity involving 126 grade XII students in Yogyakarta who had studied the reaction rate material. Student work was then analyzed using the Rasch model with the help of Winstep software. Based on the results of theoretical and empirical validity tests, the number of questions used for the pretest and posttest was 7 questions each.

Table 1. Indicator of problem-solving ability

Indicator of Problem-Solving Ability	Learning objectives	Question	
		Pretest	*Posttest*
1. Understand the problem 2. Develop a problem-solving plan 3. Implement the problem-solving plan 4. Recheck the results of the problem-solving	Describe the concept of reaction rate	1	1
	Conclude the occurrence of chemical reactions with collision theory	2-5	2-5
	Explain the factors that affect reaction rate	6	6
	Analyze the relationship between collision theory and factors that affect reaction rate	7	7

The reliability results of the problem-solving ability test based on Cronbach's alpha value of the pretest problem-solving ability were 0.62, and the posttest was 0.64. Both results are included in the moderate category, indicating reliable questions.

Data Analysis

Data analysis includes determining the n-Gain value to obtain an increase in student score results from pretest and posttest values. According to Hake (1999), the n-Gain value can be divided into several criteria, namely n-Gain ≥ 0.7 high category, 0.3 ≤ n-Gain ≤ 0.7 medium category, and n-Gain < 0.3 low category. Determining the effect of using Flipped Classroom learning based on Problem-Based Learning on students' problem-solving abilities can be seen based on the t-test. The test results can be said to be influential if the p-value <0.05.

▪ RESULT AND DISSCUSSION

The research data were obtained through a problem-solving ability test. Students were given a pretest at the beginning to determine their problem-solving ability before being given treatment. Furthermore, students were given a posttest at the last meeting to determine their problem-solving ability after being given treatment. Based on the results of the pretest and posttest, there were differences in problem-solving ability in the experimental class and the control class. This difference can be seen in Figure 1.

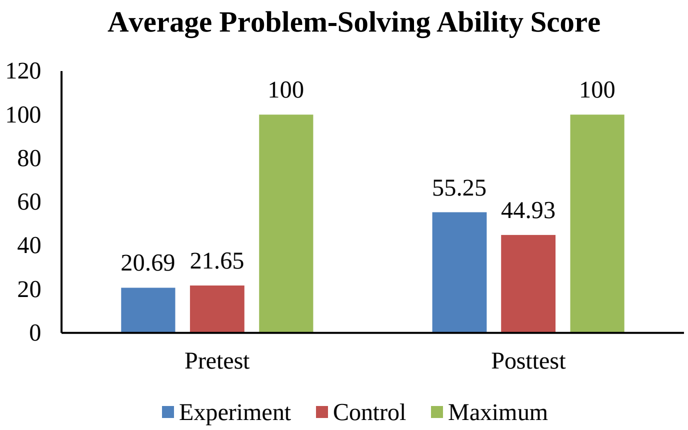

Figure 1. Average problem solving ability score

Based on the figure, in the experimental class, the average problem-solving ability of students at the pretest was 20.69 and at the posttest increased to 55.25, while the average in the control class at the pretest was 21.65 and at the posttest increased to 44.93. This shows that both classes experienced an increase, but the experimental class experienced a higher increase. In this problem-solving ability test, four indicators are measured, namely understanding the problem, preparing a problem-solving plan, implementing the problem-solving plan, and rechecking the results of the problem-solving (Heller & Heller, 2010; Yuriev et al., 2017). The magnitude of each indicator of problem-solving ability in the experimental class and control class can be seen in Figure 2.

According to the bar chart presented above, both the control and experimental classes demonstrated improvements from pretest to posttest across all four indicators. In the experimental class, the highest measurement during the pretest was related to understanding the problem, while in the posttest, it shifted to implementing the problem-solving plan. This shift can be attributed to the fact that, during the pretest, a majority of

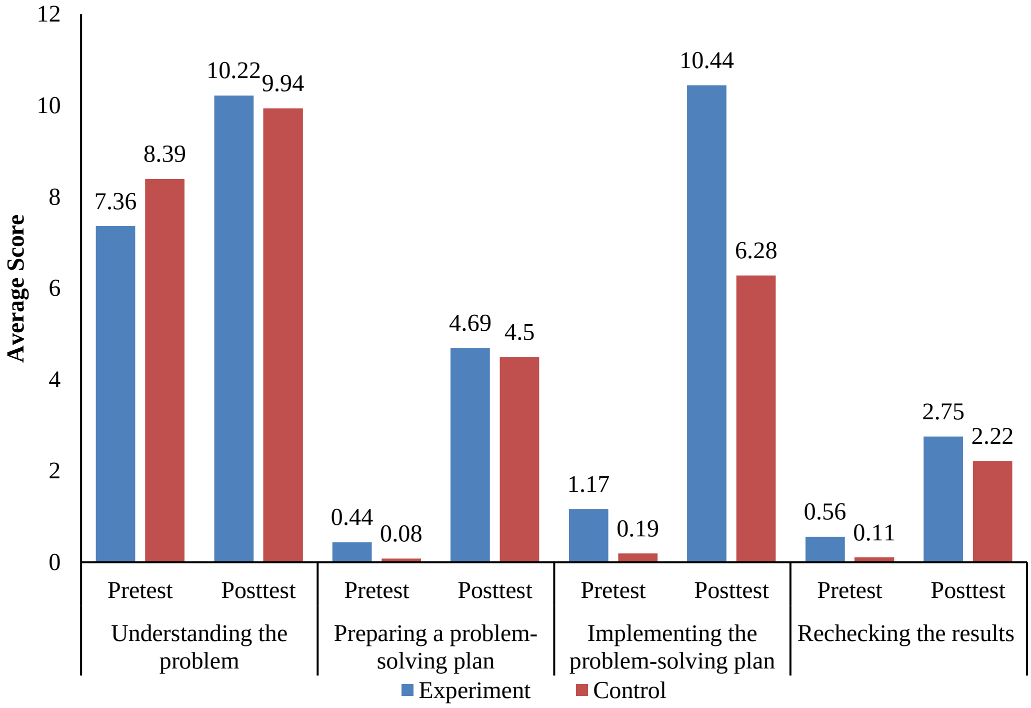

Figure 2. Average for each indicator

students in the experimental class were able to articulate what was known and asked in the questions, but struggled to provide answers due to a lack of prior exposure to the material. Once the students were introduced to the relevant information, they excelled in answering the questions, as evidenced by the elevated indicator for implementing the problem-solving plan during the posttest, indicating their ability to apply the knowledge acquired. Conversely, in the control class, the highest indicator remained consistent in understanding the problem for both the pretest and posttest phases. Students here were capable of noting the issues posed in the questions, which aligns with findings from Hidayatulloh et al. (2020), indicating that students faced no challenges in addressing questions regarding understanding the problem.

In contrast to the experimental class, which experienced an increase in the implementation stage of the plan. Students in the control class did not understand the material well in the control class. This can happen because students in the experimental class have more study time and are accustomed to solving problems at the problem-based learning stage. Students need to be accustomed to solving problems in the learning process because the learning process based on problem solving has a positive influence on critical thinking and students' problem-solving perceptions (Temel, 2014).

The lowest indicator observed in both the experimental and control classes during the pretest was the formulation of a problem-solving plan, as students were not yet able to articulate the plan they intended to follow due to a lack of exposure to the relevant material. Additionally, in the posttest, the lowest indicator identified was the process of rechecking. This occurred because most students failed to recheck their work, and they did not adequately attend to the instructions, leading them to overlook the requirement to conclude. The distinction in responses between the experimental and control classes can be illustrated in Figures 3 and 4.

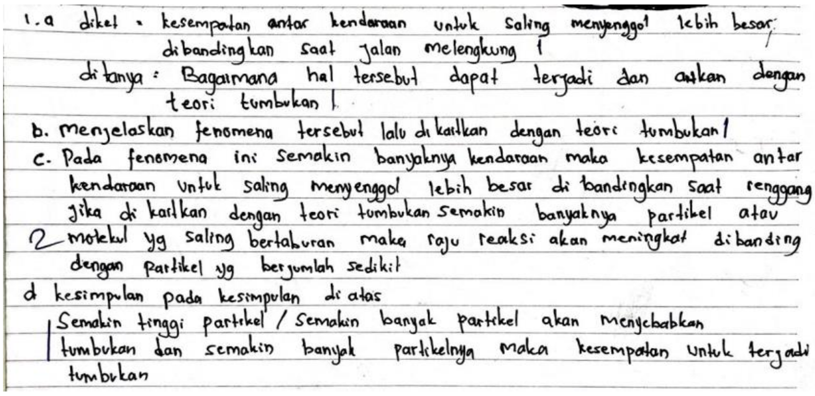
1.a diket : kesempatan antar kendaraan untuk saling menyenggol lebih besar dibandingkan saat jalan melengkung !
ditanya : Bagaimana hal tersebut dapat terjadi dan aitkan dengan teori tumbukan !
b. Menjelaskan fenomena tersebut lalu di kaitkan dengan teori tumbukan !
c. Pada fenomena ini semakin banyaknya kendaraan maka kesempatan antar kendaraan untuk saling menyenggol lebih besar di bandingkan saat renggang jika di kaitkan dengan teori tumbukan semakin banyaknya partikel atau molekul yg saling bertaburan maka laju reaksi akan meningkat dibanding dengan partikel yg berjumlah sedikit
d kesimpulan pada kesimpulan di atas
Semakin tinggi partikel / Semakin banyak partikel akan menyebabkan tumbukan dan semakin banyak partikelnya maka kesempatan untuk terjadi tumbukan

Figure 3. Example of posttest answers for students in the experimental class

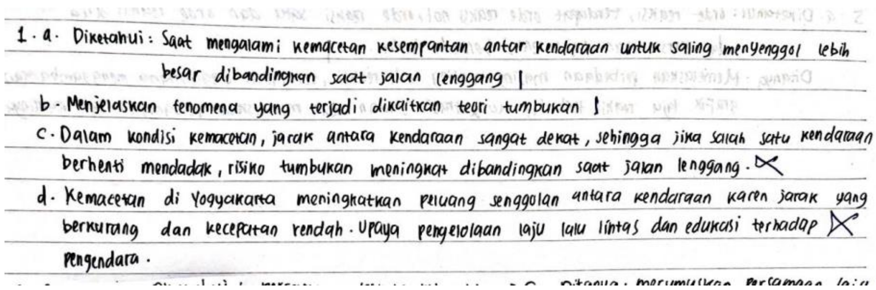
1. a. Diketahui : Saat mengalami kemacetan kesempatan antar kendaraan untuk saling menyenggol lebih besar dibandingkan saat jalan lenggang !
b. Menjelaskan fenomena yang terjadi dikaitkan teori tumbukan !
c. Dalam kondisi kemacetan, jarak antara kendaraan sangat dekat, sehingga jika salah satu kendaraan berhenti mendadak, risiko tumbukan meningkat dibandingkan saat jalan lenggang.
d. Kemacetan di Yogyakarta meningkatkan peluang senggolan antara kendaraan karen jarak yang berkurang dan kecepatan rendah. Upaya pengelolaan laju lalu lintas dan edukasi terhadap pengendara.

Figure 4. Example of posttest answers for students in the control class

Based on Figures 3 and 4, in the experimental class, students answered the questions in more detail and depth. This is because in flipped-PBL learning, students have studied more material compared to the control class. In addition, learning using flipped-PBL provides problem-solving experience during learning, so that students are accustomed to identifying problems, planning, implementing solutions, and evaluating the solutions they have made. Meanwhile, in the control class, students only study the material while in class, which results in less time for students to study, and students do not understand the stages of problem solving, which are indicators contained in each question item.

Moreover, to evaluate the enhancement in problem-solving skills and criteria before and after treatment, one can refer to the n-Gain value. The n-gain results for the experimental group are 0.438, while the control group is 0.301. These findings suggest that the problem-solving abilities of students in both the experimental and control groups fall within the moderate range, although the experimental group demonstrates a higher improvement compared to the control group. As such, the enhancement in problem-solving abilities through flipped classroom learning based on problem-based learning surpasses that of scientific learning. Following the n-gain results, a t-test was performed to assess the significant impact of flipped classroom learning grounded in problem-based learning on problem-solving skills. The t-test results indicate a significance level of 0.000, which is less than 0.005. These results indicate that there is a significant influence of Flipped Classroom learning based on Problem-Based Learning on problem-solving abilities. This is in line with research by Arnata et al. (2020), the use of Flipped-PBL learning can improve students' problem-solving abilities.

In problem solving, an important element that needs to be possessed is finding and implementing strategies to solve existing problems. Students who develop problem-solving skills are able to choose and determine the most appropriate strategy in solving problems (Yilmaz, 2022; Batlolona et al., 2018; Cahyadi et al., 2023). Student problem-solving can help students solve everyday problems and academic problems submitted by teachers (Rachmantika & Wardono, 2019). Research by Mardiansyah et al (2022) shows that low problem-solving skills are also influenced by the learning steps used, which tend not to hone students' high-level thinking skills. Teachers are more active in explaining so that communication only occurs in one direction. Therefore, by implementing flipped classroom learning based on problem-based learning where students are the focus of learning, problem-solving skills can be improved.

Learning using the flipped classroom method provides an opportunity for students to learn first before class starts. According to Delozier & Rhodes (2017), there are two activities in flipped classroom learning, namely out-of-class activities and in-class activities. Out-of-class activities are students studying material in the form of teaching modules or learning videos that are given 3-4 days before face-to-face classes. By utilizing technology in the form of learning videos, students' learning time can occur anywhere (Lo & Hew, 2017), and they can learn at their own pace (Roehling, 2018). In class, students will discuss the material that has been studied so that class time is maximized to solve problems, answer quizzes, and apply or retrieve material that they have previously studied (Subramaniam & Muniandy, 2016). Providing this material makes the interaction between students and educators more active when learning in class, and the teacher will become a facilitator (Muir & Geiger, 2015).

Learning with the problem-based learning model is carried out sequentially. At the problem orientation stage, students are faced with real problems, such as some of those contained in the LKPD, namely iron rust, fruit rot, and paper burning, which are related to factors that affect the reaction rate. After problem orientation, students are organized into study groups and given several problems to solve. The formation of this group is so that learning is carried out collaboratively between students and given a clear division of tasks so that scientific interactions are created to build knowledge (Shoimin, 2017). Furthermore, the teacher guides students to conduct independent and group investigations. At this stage, students seek information from various sources to be able to answer questions given independently or in groups. After that, students develop and present the results of their work by making presentations in front of the class. After making a presentation, the last stage is to analyze and evaluate the problem-solving process. At this stage, students and teachers will analyze and evaluate the results of the discussions that have been presented.

This experimental class learning is different from the control class learning, which uses a scientific approach. However, the scientific approach is included in active learning. The scientific approach applied in the control class has 5M stages, namely observing, asking, collecting, associating, and communicating (Setyawan, 2024). The process at this learning stage is almost the same as in the experimental class; students are given the opportunity to discuss in groups. However, what is different from the experimental class is that in the control class, students get material during face-to-face learning in the classroom, and the teacher is the center of learning. Hence, the knowledge construction process is not as good as in the experimental class. This is evident when, in the experimental class, students who have studied the material first try to find solutions to problems by discussing them in groups. In contrast, the control class tends to ask more questions about the material to the teacher before discussing with group friends.

Therefore, the use of flipped classroom learning based on problem-based learning can improve students' problem-solving abilities. This approach allows learners the flexibility to engage with content in a manner that suits their learning preferences, regardless of location (Hwang & Chen, 2023). Students have the opportunity to view instructional videos, read relevant materials, and tackle questions individually, which fosters their knowledge acquisition and promotes autonomy in learning (Mudhofir, 2021). In utilizing the flipped classroom approach, students are expected to grasp the foundational concepts prior to attending class, facilitating their participation in discussions and collaborative problem-solving during class time (Ranga, 2020). The interactive discussions about problem-solving that occur during in-person sessions empower students to explore solutions that align with the problem-based learning framework. This model focuses on real-world issues, thereby enhancing students' capabilities in problem-solving (Eggen & Kauchak, 2012). Furthermore, employing this model enables students to develop skills in teamwork, engage in dialogue, seek pertinent information, gather data, and evaluate potential solutions (Mataka & Kowalske, 2015).

▪ CONCLUSION

Research indicates that the experimental class employing a flipped classroom approach, grounded in problem-based learning, significantly enhances students' problem-solving skills. This method encourages independent learning, allowing students to tackle problems through discussions and knowledge acquisition from diverse sources. Students can develop their problem-solving abilities across four key indicators: comprehending the problem, devising a problem-solving strategy, executing this strategy, and verifying the outcomes of their solutions. Therefore, flipped classroom learning based on problem-based learning can be used by educators to improve problem-solving abilities in other chemical materials and can be one of the innovative learning options that can be applied to students.

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