

THE EFFECT OF THE E-COMIC-ASSISTED PROBLEM BASED LEARNING (PBL) MODEL ON STUDENTS' CRITICAL THINKING AND ARGUMENTATION SKILLS ON PETROLEUM MATERIALS

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ABSTRACT

The background of this research is based on the low level of students' higher-order thinking skills, especially critical thinking and argumentation skills, due to the teacher-centered learning process and minimal use of interesting and contextual media. This study aims to determine the effect of the Problem Based Learning (PBL) model assisted by e-comics on students' critical thinking and argumentation skills on petroleum material. The study used a quasi-experimental method with a nonequivalent control group design. The research sample consisted of an experimental class learning with the PBL model assisted by e-comics and a control class using conventional learning. The research instruments were critical thinking ability tests, argumentation ability tests, and observation sheets for teacher and student activities. The results showed that the application of the PBL model assisted by e-comics had a significant effect in improving students' critical thinking and argumentation skills compared to conventional learning. Students in the experimental class showed higher improvements in their ability to analyze, evaluate information, construct arguments, provide supporting evidence, and draw logical conclusions. E-comics media contributed to facilitating the understanding of abstract petroleum concepts through engaging narrative visualization. Thus, the e-comic-assisted PBL model is effective in improving students' critical thinking and argumentation skills on petroleum material.

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INTRODUCTIONS

MAN 2 Indragiri Hilir School (INHIL) is included in the education level after junior high school as a continuation to prepare students to continue to the higher education level. As a preparation for this, students at MAN

2 INHIL are equipped with various scientific fields, including chemistry. Chemistry subjects cover some material such as petroleum from preliminary studies. Information was obtained that chemistry learning, especially petroleum materials, has so far been more oriented to educators, not to students or collaboration between educators and students (Nugraheni et al., 2019).

From the preliminary study, information was also obtained that chemistry learning at MAN 2 INHIL there are several problems that occur in the learning process, including (1) students lack confidence in their own abilities, (2) students are used to waiting for answers from teachers and are not used to thinking independently, (3) the classroom environment does not encourage the courage to express opinions because students are worried about being criticized or blamed if they think differently, (4) there are no teaching aids, videos, or contextual learning resources that support exploration and discussion, eventually learning becomes rigid and sourced from textbooks, and (5) students tend to be bored and not motivated to follow the learning process because the material is difficult to understand and students lack literacy, (6) the learning process is not yet oriented to develop critical thinking skills and teachers still use the lecture method. Based on the problems found, that there is still a low level of critical thinking and argumentative skills and student learning outcomes. For example, students have difficulty in reasoning and data interpretation based problems (e.g., distillation charts or reaction diagrams) that are often confusing. Students are used to memorizing, not analyzing.

The teacher-centered learning process, students are less trained to develop their critical thinking skills and argumentative skills because students are only given information that the teacher knows from the source books used. In analyzing problems, students have not been able to analyze the existing information. They still struggle to find and structure information into smaller pieces to recognize patterns or relationships. When given the opportunity to ask questions or give opinions, only a few students are able to express their opinions. In expressing opinions / ideas / ideas is only limited to statements (claims), not even able to explain accurate statements according to the problems presented (Dewina et al., 2017).

The critical thinking and argumentation skills of MAN 2 INHIL students are still relatively low, especially in terms of mastery of the concept of chemical materials such as petroleum, as well as in the ability to think critically and deliver arguments. This can be seen from the fact that there are still many students who rely on memorization, are less able to explain concepts logically, and have difficulty understanding reasoning-based or data-based problems. In addition, the lack of active participation in class discussions, lack of confidence, and dependence on teachers indicate that the ongoing learning process has not been able to optimize the potential of students' high-level thinking. With these conditions, more innovative, interactive, and student-centered learning efforts are needed to improve the quality of overall learning outcomes.

Based on the results of a preliminary study at MAN 2 INHIL, it is known that students still show critical thinking skills and low argumentation skills in the learning process. Students tend to be passive, lack confidence, and are afraid to present arguments because they are afraid of being wrong or criticized. This condition shows the need for a learning approach that can develop high-level thinking skills and the ability to express opinions logically and systematically. The learning model that is expected in an effort to improve critical thinking and argumentation skills, especially students' critical thinking and argumentation skills on petroleum materials, is the PBL model. This model was chosen because it is able to encourage students to be active in the learning process through contextual problem solving, so that they not only understand concepts theoretically, but also are able to apply them in real situations. With PBL, students are trained to think logically, collaborate, express opinions, and build high-level thinking skills.

The PBL model was chosen because of its many advantages that make the learning process more successful and meaningful. Through PBL, students not only passively receive knowledge, but are invited to actively solve real problems relevant to daily life. This encourages students to think critically, and is able to develop argumentative skills in finding solutions (Syamsinar, 2023).

The learning model chosen at MAN 2 INHIL to overcome low learning outcomes, especially in students' critical thinking and argumentation skills on chemistry materials is PBL. The selection of this model is based on the characteristics of PBL which emphasizes the active involvement of students in the learning process through real and

contextual problem-solving. This model is considered relevant to encourage students to be more independent in their thinking, able to develop arguments logically, and build a deeper conceptual understanding through discussion and exploration. With the support of digital learning media such as e-comics, the implementation of PBL is expected to be able to create a more interesting, meaningful, and effective learning atmosphere at MAN 2 INHIL. Because e-comics are able to combine text, images, and storylines so as to create a fun and non-monotonous learning atmosphere. With an attractive display, students are more focused and motivated to follow the learning process. In addition, e-comics can present abstract concepts to be more concrete through illustrations, making it easier to understand, especially in complex materials such as chemistry.

RESEARCH METHODS

This study uses a quantitative method with a Quasi Experimental scheme of the Non Equivalent Control Group Design type. The research was conducted in two classes consisting of an experimental class and a control class (comparator). The experimental class was given a treatment in the form of learning using the e-comic-assisted PBL model. Meanwhile, the control class did not use the e-comic-assisted PBL model, only using the conventional learning model.

The research was carried out at MAN 2 Indragiri Hilir which is located in JL. Education No. 113 Kuala Enok Village, Tanah Merah District, Indragiri Hilir Regency, Riau. This research is planned for the Odd Semester of 2025. The subjects in this study are 40 students in grade XI MAN 2 INHIL. Meanwhile, the object of this study is the use of the Problem Based Learning (PBL) model assisted by E-comic which is carried out based on the implementation steps.

The population in this study is 2 classes with 40 students, According to Amin et al, (2023) The sample can be simplified as part of the actual population as the source of data in the study. The sampling technique of this study uses the total sampling technique. Total Sampling is a sample selection method in which all members of the population are used as research subjects. If the population is less than 100, it is recommended to use total sampling as all members of the population participate as subjects for the study (Raya et al, 2025). In this study, the research sample is class XI MAN 2 Inhil, one experimental class and one control class.

This study uses tests in the form of essay questions given in the form of pretest and posttest, including results to find out how students respond to the influence of PBL using a likert scale questionnaire (Novianti, et al, 2020). In this study, the researcher used several techniques to collect data, namely using a test instrument that measures students' critical thinking and argumentation skills presented in the form of 5 essay questions to test students' critical thinking and argumentation skills.

The instruments that will be validated in this study are in the form of observations, pretest and posttest questions, in tracing whether the instrument is suitable for use in research. The research instrument was carried out in consultation with expert lecturers. This aims to examine the content of the instrument that has become a representative of the measured aspect. The data analysis techniques in this study are in the form of normality test, homogeneity test and t test.

RESULTS AND DISCUSSION

Research Results

Based on the results of the study, data was obtained on the Effect of the E-Comic-assisted Problem Based Learning (Pbl) Model on students' critical thinking and argumentation skills on petroleum materials, which was held in October-November 2025. The normality test was carried out to determine whether the data obtained was normally distributed and the results showed a significance value of more than 0.05, so that the data was declared normal. The homogeneity test was used to see the similarity of variance between groups, and the results showed a significance value (Based on Mean) > 0.05 , which means that the data is homogeneous. Next, test the hypothesis with the t-test. The t-test uses the paired Sample T test technique, showing that the significance value of the sig. $0.000 < 0.05$ on the Critical Thinking Ability variable, then showing that the value of sig. $0.000 < 0.05$ on the argumentation variable

which means that there is an influence of the e-comic-assisted PBL model on students' critical thinking skills and argumentation on petroleum materials in MAN 2 INHIL. The full results of the research are described as follows.

Critical Thinking Skills

Descriptive test

Descriptive tests are used to find out general descriptions such as average, median, maximum value, minimum value and sum (Wulandari, et al, 2021). The following analysis results can be seen in the descriptive statistics table below:

Table 1. Descriptive Statistics Results of Critical Thinking

Descriptive Statistics								
	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest Experiments	20	68	16	84	932	46.60	18.819	354.147
posttest experiment	20	72	24	96	1412	70.60	15.371	236.253
Pretest Control	20	52	24	76	976	48.80	15.168	230.063
Posttest control	20	64	20	84	1004	50.20	18.603	346.063
Valid N (listwise)	20							

Based on the table above, it shows descriptive statistical data on the pretest of the experimental class referring to the number of respondents in the control class (N) 20. The minimum score of students is 16 and the maximum score is 84. The sum score is 932. The average score of students is 46.60. Furthermore, in the posttest of the experimental class, referring to the number of respondents in the control class, it is (N) 20. The minimum student score is 24 and the maximum score is 96. The sum score is 1412. The average student score is 70.60.

Then, in the control class pretest, the minimum student score was 24 and the maximum score was 76. The sum score was 976. The average student score was 48.80. And in the control class posttest, the minimum student score was 20 and the maximum score was 84. The sum score was 1004. The average student score was 50.20. To see the diagram of the average scores from each pretest and posttest of the experimental class and control class for students' critical thinking skills, see the diagram below.

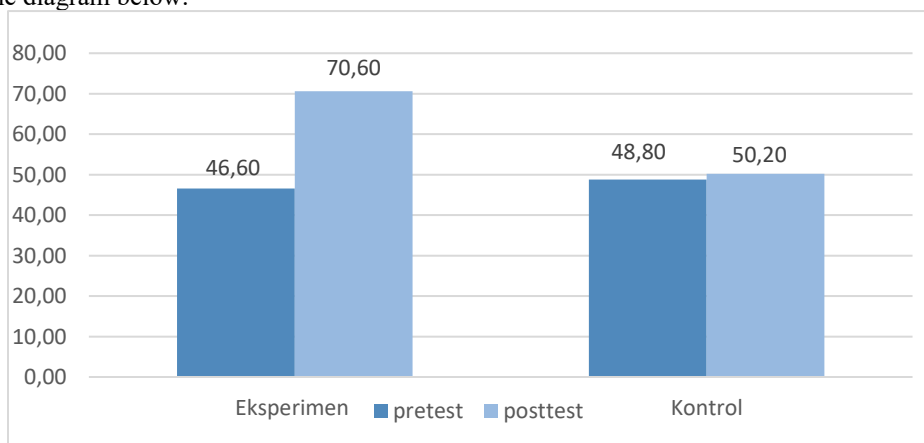


Figure 1. Average Score of Students' Critical Thinking Ability

Normality Test

The normality test is a test used to find out whether the data obtained is normally distributed or not, so that it can be used in parametric statistics (Isnaini et al, 2025). The analysis was carried out using the SPSS Statistics 25 program with the Kolmogorov-Smirnova Technique, In the normality test, there is an indicator called the significance value. If the data has a significance value of 0.05, it can be said that the data is normal (Wulandari, et al, 2021). The normality test in this study is as follows:

Table 2. Results of the Normality Test of Critical Thinking

Tests of Normality				
	Classes	Kolmogorov-Smirnov ^a		
		Statistic	df	Sig.
Critical Thinking Skills	Pretest Experiments	.105	20	.200*
	posttest experiment	.145	20	.200*
	Pretest Control	.119	20	.200*
	Posttest control	.139	20	.200*
*. This is a lower bound of the true significance.				
a. Lilliefors Significance Correction				

The results of the data normality test in the table above show that the Sig value in the experimental class pretest is $0.200 > 0.05$, the experimental class posttest is $0.200 > 0.05$, the control class pretest is $0.200 > 0.05$ and the control class posttest is $0.200 > 0.05$. Based on the two classes, the resulting value was more than 0.05, so it can be concluded that the data on students' critical thinking skills in the experimental class and the control class were normally distributed.

Homogeneity Test

The homogeneity test is performed to show that the difference that occurs in the parametric statistical test. The analysis was carried out using the SPSS Statistics 25 program, namely the Test of Homogeneity of Variance, The guideline for drawing conclusions is that if the significance value (sig) Based on Mean > 0.05 then the data variance is homogeneous and if the significance value (sig) Based on Mean < 0.05 then the data variance is not homogeneous (Usmadi, 2020). So the results of the homogeneity test are obtained as follows:

Table 3. Results of the Homogeneity Test for Critical Thinking

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Critical Thinking Skills	Based on Mean	.967	3	76	.413

From the calculation of the homogeneity test using the *Homogeneity of Variance test* at the significance level of $\alpha = 0.05$ that the sig value based on mean $0.413 > 0.05$ means that the experimental and control class data data is the same or homogeneous.

T Test

(Magdalena & Krisanti, 2019) The Effect of the E-Comic-Assisted PBL Model on Students' Critical Thinking Skills on Petroleum Materials at MAN 2 INHIL. Hypothesis test using the Paired Sample T-test technique (Magdalena & Krisanti, 2019). Furthermore, to support the research hypothesis above, it is formulated as follows:

Table 4. Hypothesis Testing Results with Paired Sample T-test Critical Thinking

Variable	Classes	Sig
Critical Thinking Skills	experiment	0,000
	control	0,776

Based on Table 4.4, the results of the Paired Sample t-test showed that in the experimental class, a significance value of 0.000 ($p < 0.05$) was obtained, so that there was a significant difference between the pretest and posttest scores of students' critical thinking skills after applying the e-comic-assisted PBL model to petroleum materials at MAN 2 INHIL; while in the control class, a significance value of 0.776 ($p > 0.05$) was obtained, which showed no difference significant difference between the pretest and posttest scores of students' critical thinking skills without the application of the e-comic-assisted PBL model, so it can be concluded that the application of the e-comic-assisted PBL model has a significant effect on improving students' critical thinking skills.

Student Arguments

Descriptive test

The following analysis results can be seen in the descriptive statistics table below:

Table 5. Descriptive Statistics Argumentation Results

Descriptive Statistics								
	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest Experiments	20	60	30	90	1090	54.50	16.295	265.526
posttest experiment	20	45	55	100	1605	80.25	11.639	135.461
Pretest Control	20	45	35	80	1110	55.50	12.660	160.263
Posttest control	20	45	45	90	1205	60.25	11.751	138.092
Valid (listwise)	N 20							

Based on the table above, it shows the *Descriptive statistical data* In the *pretest* of the experimental class, the number of respondents in the control class refers to (N) 20. The student's minimum score is 30 and the maximum score is 90. The sum value is 1090. The average student score is 54.50. Furthermore, in the *posttest* of the experimental class, the number of respondents in the control class was (N) 20. The student's minimum score is 55 and the maximum score is 100. The sum value is 1605. The average score of students is 80.25.

Then in the *control class pretest*, it was known that the minimum score of students was 35 and the maximum score was 80. The sum value is 1110. The average score of students is 55.50. And in the *posttest* of the control class, it was known that the minimum score of students was 45 and the maximum score was 90. The sum value is 1205. The average student score is 60.25. To see the diagram of the average score results of each of the experimental class pretest posttest and the student argumentation control class, you can see the diagram below.

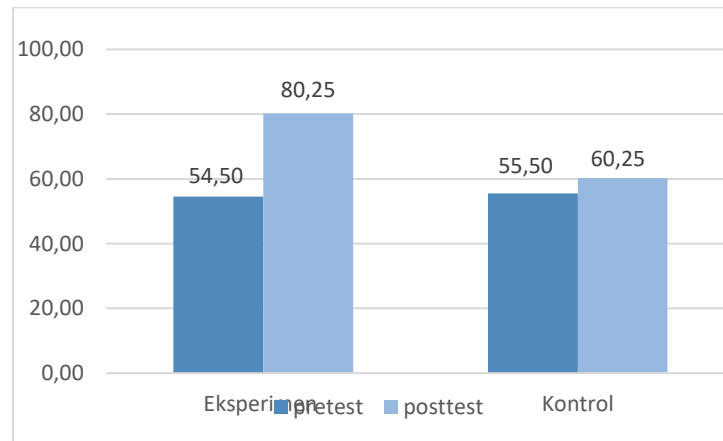


Figure 2. Average Student Argumentation Score

Uji Normalitas

The normality test in this study is as follows:

Table 6. Results of the Argumentative Normality Test

Tests of Normality				
	Classes	Kolmogorov-Smirnov ^a		
		Statistic	df	Sig.
Argumentation	Pretest Experiments	.188	20	.063
	posttest experiment	.158	20	.200*
	Pretest Control	.189	20	.060
	Posttest control	.158	20	.200*

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The results of the data normality test in the table above show that the Sig value in the experimental class pretest was $0.063 > 0.5$, the experimental class posttest was $0.200 > 0.5$, the control class pretest was $0.060 > 0.5$ and the control class posttest was $0.200 > 0.5$. Based on the two classes, the resulting value is more than 0.05 so that it can be concluded that the student argumentation data in the experimental class and the control class are normally distributed.

Homogeneity Test

The homogeneity test in this study is as follows:

Table 7. Results of the Argumentation Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Argumentation	Based on Mean	.838	3	76	.477

From the calculation of the homogeneity test using the *Homogeneity of Variance test* at the significance level of $\alpha = 0.05$ that the sig value based on mean $0.477 > 0.05$ means that the experimental and control class data is the same or homogeneous.

T Test

The homogeneity test in this study is as follows:

Table 8. Hypothesis Testing Results with Paired Sample T Test Argumentation

Variable	Classes	Sig
Argumentasi	experiment	0,000
	control	0,211

Based on Table 4.8, the results of the Paired Sample t-test showed that in the experimental class, a significance value of 0.000 ($p < 0.05$) was obtained, so that there was a significant difference between the pretest and posttest scores of students' argumentation skills after applying the e-comic-assisted PBL model to petroleum materials at MAN 2 INHIL; while in the control class, a significance value of 0.211 was obtained ($p > 0.05$), which shows that there is no significant difference between the pretest and posttest scores of students' argumentation skills without the application of the e-comic-assisted PBL model, so it can be concluded that the application of the e-comic-assisted PBL model has a significant effect on improving students' argumentation skills.

Critical Thinking and Argumentation

The t-test in this study is table 9.

Table 9 Hypothesis Testing Results with Independent Sample T Test Critical Thinking and Argumentation

Variable	T-Count	T-Table	Sig
Critical Thinking and Argumentation	2.238	1.685	0,031

Based on table 4.9 obtained, it was obtained that t-count has a value greater than t-table ($2,238 > 1,685$) or sig value. $0.031 < 0.05$. Thus, it can be concluded that the tcount $>$ ttable or sig value is less than 0.05. So it can be concluded that there is an interaction between the PBL model on critical thinking skills and students' arguments on petroleum learning at MAN 2 INHIL.

Observation Results of Teachers and Students of Problem Based Learning (PBL) Model Assisted by E-Comic

The results of the recapitulation of the results of the observation of teacher and student activities in learning on petroleum materials using the *E-Comic-Assisted Problem Based Learning (PBL) Model* from the first meeting to the third meeting.

Recapitulation of Teacher Activity Observation

The results of the recapitulation of teacher activity observations using the *E-Comic-Assisted Problem Based Learning (PBL) Model* on petroleum materials are as follows:

Table 10. Recapitulation of Observation Results of Teacher Activities

No	Learning activities	Observations			
		1	2	3	4
1	The teacher explains the learning objectives, explains the important requirements that must be provided and motivates the learners to engage in problem-solving activities.	4	5	5	5
2	Help learners define problems and organize study tasks related to the problem.	3	4	5	5
3	Teachers encourage students to gather information, behavior that is appropriate to the experiment, look for explanations and solutions.	3	4	5	5
4	Teachers assist students in planning and preparing appropriate work such as reports, videos, models, and help them share their work with other participants.	2	3	4	5
5	Teachers help learners to reflect on their research and the processes they use.	3	4	5	5
Total score		15	20	24	25
Maximum score		25	25	25	25
Percentage		60%	80%	96%	100%
Criteria		Pretty good	Good	Excellent	Excellent

Recapitulation of Student Activity Observation

The results of the recapitulation of student activity observations using the *E-Comic-Assisted Problem Based Learning (PBL)* Model on petroleum materials are as follows:

Table 11. Recapitulation of Student Activity Observation Results

No	Learning activities	Observasi			
		1	2	3	4
1	Students understand learning objectives, provide essential requirements and prepare themselves to engage in learning activities	3	4	5	5
2	Learners define problems and prepare to receive study assignments related to problems.	4	5	5	5
3	Learners gather information, behave in accordance with the experiment, look for explanations and solutions.	3	4	5	5
4	Students plan and prepare work and share work with other students.	2	3	4	5
5	Learners reflect on the research and processes used.	2	3	4	5
Total score		14	19	23	25
Maximum score		25	25	25	25
Percentage		56%	76%	92%	100%
Criteria		Pretty good	Good	Excellent	Excellent

Tables 10 and 11 show the results of the recapitulation of the results of observation of teacher and student activities in learning using *the Problem Based Learning (PBL) Model Assisted by E-Comic* on petroleum materials from the first meeting to the fourth meeting in the experimental class, where the results of the observation of teacher activities reached a percentage of 100% which is classified as very good. Students can also use the *E-Comic-Assisted Problem Based Learning (PBL) Model* well, with a success rate of 100%.

Discussion

The Effect of E-comic-Assisted PBL Model on Experimental Classes

In the experimental class, learning was applied with the e-comic-assisted Problem Based Learning (PBL) model on petroleum materials. The results showed a significant improvement in students' critical thinking skills after the treatment was given. The average pretest score of 46.60 increased to 70.60 on the posttest, indicating a meaningful change in cognitive ability. This improvement indicates that the learning process encourages students to think more analytically and reflectively. Students no longer just receive information, but actively build understanding through problem-solving. Thus, the application of PBL assisted by e-comic has proven to be effective in improving students' critical thinking skills.

Conceptually, the PBL syntax which includes problem orientation, organization of activities, investigation, solution development, and reflection plays an important role in stimulating higher-level thinking. Each stage of learning provides students with the opportunity to identify problems, formulate hypotheses, and evaluate the

information obtained. When students are faced with contextual problems about petroleum, they are encouraged to relate the concept of chemistry to real phenomena. This process encourages cognitive activity at the level of analysis, evaluation, and conclusion drawn. Group discussion activities strengthen the process of elaborating ideas between students. Therefore, PBL functions as a systematic learning framework to develop critical thinking skills.

The use of e-comic in learning also strengthens the effectiveness of PBL implementation. Visual media helps students understand the context of the problem in a more concrete and interesting way. The presentation of problems in the form of visual stories makes it easier for students to identify the main issues that need to be analyzed. This reduces the initial cognitive load of students in understanding problem situations. With a better understanding of the context, students can focus more on the process of analyzing scientific concepts. E-comic media also increases student involvement during learning. As a result, students' critical thinking process develops more optimally.

In addition to critical thinking, students' argumentation skills in the experimental class have also increased significantly. The average pretest score of 54.50 increased to 80.25 in the posttest after the implementation of PBL assisted by e-comic. This increase shows that students are increasingly able to express their opinions logically and evidence-based. Through discussion and investigation, students are trained to make claims, present supporting data, and provide rational reasoning. Interaction between students encourages the process of responding to each other and revising arguments. Thus, the combination of PBL and e-comic is effective in developing students' scientific argumentation skills.

Influence of PBL Model on Control Class

In the control class, the learning process is carried out with a conventional teacher-centered approach. This learning pattern places the teacher as the main source of information, while the student plays the role of the recipient of the material. Learning interactions tend to be one-way and limited to verbal delivery of concepts. This condition causes students' cognitive involvement in the learning process to be relatively low. Students are not given adequate space to construct knowledge independently. As a result, the potential for the development of high-level thinking skills is not optimally facilitated.

The impact of the conventional approach can be seen in the achievement of students' critical thinking skills in the control class. The average pretest score of 48.80 only increased to 50.20 in the posttest. This relatively small increase indicates that the learning process does not encourage students to conduct in-depth analysis, evaluation, and conclusions. Learning activities emphasize more on conveying information than processing information critically. Students tend to memorize concepts without understanding their relationship to contextual problems. This condition causes critical thinking indicators such as interpretation, analysis, inference, and evaluation to not develop significantly. Thus, conventional learning is less effective in improving students' critical thinking skills.

The limitations of the conventional approach are also reflected in the low improvement of students' argumentative skills in the control class. The average pretest score of 55.50 only increased to 60.25 in the posttest. This increase shows that students have not been trained to express opinions in a systematic and evidence-based manner. The learning process with minimal discussion reduces students' opportunities to express their views, test opinions, and defend arguments rationally. Students receive information more often than they produce arguments. As a result, the ability to formulate claims, present evidence, and provide scientific reasoning is not optimally developed. This shows that conventional learning has not supported the strengthening of students' argumentative competence.

The absence of collaborative activities and problem-solving in conventional learning also affects the low achievement of the two variables studied. Learning is not designed to engage students in problematic situations that demand analysis and decision-making. Students are not accustomed to asking critical questions or evaluating information independently. The learning process also does not encourage the exchange of ideas between students. This condition causes students' learning experiences to be passive and less meaningful. As a result, critical thinking and argumentation skills do not develop sustainably. This shows that the learning approach greatly determines the quality of students' cognitive achievement.

When compared to the experimental class, the difference in achievement between the two classes is very obvious. The control class showed only minimal improvement in critical thinking and argumentative skills. In contrast, the experimental class showed a significant improvement after the implementation of the e-comic-assisted PBL model. This distinction confirms that learning that places students as active subjects has a greater impact on the development of higher-level thinking skills. Problem-based learning provides space for students to construct knowledge through a process of inquiry. Thus, the effectiveness of learning is greatly influenced by the models and strategies used.

The findings of this study show that conventional learning is inadequate in developing students' critical thinking and argumentative skills. This approach tends to emphasize aspects of knowledge transmission rather than the development of high-level cognitive skills. The difference in results between the control class and the experimental class reinforces the importance of implementing innovative learning models that are oriented to student activities. The e-comic-assisted Problem Based Learning model has proven to be more effective in facilitating the critical thinking process and strengthening argumentation skills. Therefore, teachers need to consider using learning models that encourage active student participation. The implementation of the right learning model is a key factor in improving the quality of learning outcomes.

The Influence of PBL on Students' Critical Thinking and Argumentation Skills

An independent t-test was conducted to determine the difference in posttest results between the experimental class and the control class after the application of the learning model. This test aims to assess the effectiveness of the e-comic-assisted Problem Based Learning model compared to conventional learning. The analysis was carried out separately for each variable, namely critical thinking ability and argumentation ability. This approach is more methodologically precise because each variable has different measurement characteristics. The test is carried out after the data is declared to be normally distributed and homogeneous. With the fulfillment of the parametric test prerequisites, independent t-test results can be interpreted validly.

The results of independent t-tests on the critical thinking ability variable showed a significant difference between the experimental class and the control class. The significance value obtained is less than 0.05, so the null hypothesis is rejected. These findings show that the results of the posttest of students' critical thinking skills in the experimental class were higher than those in the control class. These differences reflect the positive influence of the application of the e-comic-assisted PBL model on the development of high-level thinking skills. Students in the experimental class are better able to analyze problems, evaluate information, and draw logical conclusions. This shows that problem-based learning has a real impact on the quality of students' thinking processes.

On the argumentability variable, the results of the independent t-test also showed significant differences between the experimental class and the control class. The significance value obtained was below the significance level of 0.05, so it can be concluded that there is a difference in the average results of the posttest of students' argumentation skills between the two classes. These findings indicate that students who learned with the e-comic-assisted PBL model had better the ability to construct arguments than students in the control class. Students in experimental classes are more skilled at making claims, presenting evidence, and providing relevant reasoning. The learning process that emphasizes discussion and problem-solving contributes to improving the quality of students' scientific arguments. Thus, PBL assisted by e-comic is effective in developing argumentative competence.

The difference in achievement between the experimental class and the control class is not only statistically significant, but also pedagogically meaningful. Problem-based learning provides a learning experience that demands active cognitive and social engagement of students. Students are involved in the process of identifying problems, seeking information, and developing solutions collaboratively. These activities encourage the formation of a deeper conceptual understanding. In addition, the use of e-comic media helps students understand the context of the problem visually and concretely. The combination of the PBL approach and e-comic media strengthens the process of internalizing concepts and developing high-level thinking skills.

The results of this study show that the application of the e-comic-assisted PBL model has a positive impact on two important aspects of science learning, namely critical thinking skills and argumentation skills. Both of these

abilities are essential competencies in 21st century learning. Improved critical thinking skills show that students are better able to process information analytically and reflectively. Improved argumentation skills show that students are increasingly skilled at expressing opinions logically and based on evidence. Thus, the e-comic-assisted PBL model not only improves cognitive achievement, but also the quality of students' scientific thinking process. This confirms the relevance of the model to be applied in chemistry learning.

The difference in posttest results between the experimental class and the control class strengthened the effectiveness of the e-comic-assisted PBL model compared to conventional learning. Student-centered learning has been shown to be more able to develop critical thinking and argumentation skills simultaneously. These findings provide practical implications for teachers to adopt problem-based learning models supported by contextual visual media. The implementation of the e-comic-assisted PBL model can be a strategic alternative in improving the quality of chemistry learning, especially in contextual materials such as petroleum. Thus, the results of this study support the use of innovative learning models in improving the quality of student learning processes and outcomes.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the application of the Problem Based Learning (PBL) model assisted by e-comics has a significant influence on improving students' critical thinking and argumentation skills on petroleum materials. This improvement can be seen in all indicators of critical thinking, ranging from the ability to provide simple explanations, analyze and evaluate problems, to compile follow-up explanations and draw conclusions. The active involvement of students in the problem-solving process through the PBL stage, supported by contextual visualization from the e-comic, helps them understand concepts in a more concrete and systematic way. In addition, the quality of students' argumentation also improved significantly in the aspects of claim, data, warrant, backing, and rebuttal because learning encourages the preparation of evidence-based arguments and logical analysis. The learning process went very well, as shown by the teacher's consistency in implementing the PBL syntax and optimal student participation at each stage, so as to create an active, interesting, and meaningful learning atmosphere.

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