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Implementation of Problem-Based Learning-Stem Strategy on Students' Conceptual Understanding and Critical Thinking in Fundamental of Chemical Equilibrium

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ABSTRACT

This research aims to determine differences in students' conceptual and critical thinking of XI High School Students that teach using Problem Based Learning-STEM strategy on learning chemical equilibrium. This research use design quasi-experimental factorial 2x2 design with convenience sampling. Instruments used in this research are students' conceptual and critical thinking tests. The result shows that (1) there are differences students' conceptual and critical thinking in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning Strategy, (2) there are differences in students' conceptual and critical thinking based on initial abilities in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy, (3) there is no interaction of Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' conceptual and critical thinking.

I. Introduction

As education develops in Indonesia, students are required to have more critical thinking skills and mastery of concepts. Critical thinking is a process of conceptualizing, implementing, synthesizing, and evaluating information from the results of observation, experience, reflection, reasoning, or communication as a reliable guide in action (Hapiziah et al., 2017). Meanwhile, understanding the concepts, principles, and scientific processes requires mathematical reasoning (Adeleke, 2007). Mathematical abilities can improve problem solving and a positive attitude towards chemistry (Merdekawati, 2013). Students with good mathematical skills are better prepared to learn chemistry than students with less mathematical abilities. Critical thinking and concept understanding are critical in evaluating the information received and reducing the risk of acting based on wrong reasoning.

In chemistry, students' difficulties in learning chemistry can be caused by (1) difficulties in understanding terms, the difficulty is because most students only memorize terms and do not correctly understand the meaning of terms that are often used in teaching chemistry, (2) difficulties in understanding the concept of chemistry. In general, the concepts in chemistry are complex concepts so students are required to understand these concepts correctly and deeply (Rumansyah, 2002). One of the complex concepts in learning chemistry is chemical equilibrium. Chemical equilibrium material is a material that requires the use three representations there are macroscopic, microscopic, and symbolic (Demircioğlu et al., 2013).

Based on the problems that showed above, it can be concluded that the conceptual understanding and critical thinking skills of students in the material of chemical equilibrium are still low. Conceptual understanding and critical thinking skills are very important because when we understand a certain concept, it will make it easier for students to learn the material in class and its application in everyday life (Muhali et al., 2021).

School as an institute that provides education has a responsibility in developing students' conceptual understanding and critical thinking skills (Hasnunidah et al., 2020). Conceptual understanding and critical thinking skills must be applied to every lesson. Science is concerned with finding out about nature systematically through a process of discovery. Chemistry is a branch of science with discovery to find concepts. Chemistry learning must be applied by learning to stimulate the development of students' critical thinking skills. In fact, the

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learning process at school has not triggered students to develop critical thinking skills. Critical thinking skills can provide encouragement for students to learn independently and can solve the problems by themselves (Hapiziah et al., 2017). This is supported by the research of Yanwar & Fadila (2019), which that there is an influence on students who have high, medium, and low learning independence categories on their mathematical critical thinking skills.

Problem Based Learning model (PBL) is a learning model that emphasizes the activeness of students by using all senses and imagination in understanding the concepts being learned. Problem Based Learning consists of presenting meaningful problem situations that can make it easy for students to carry out investigations and obtain concepts learned through investigative activities (Ibrahim & Mohamad, 2004). That is because in the PBL strategy, students are required to find their own answers by using their critical thinking skills of students to form a concept about the material being studied (Yulianti & Gunawan, 2019). Problem Based Learning help students to develop critical thinking skills, problem-solving, and intellectual skills (Trianto, 2007).

Problem Based Learning (PBL) needs to follow up the era of globalization, which is by integrating Science, Technology, Engineering, and Mathematics (STEM) (Wan Husin et al., 2016). The relationship between science and technology and other sciences cannot be separated in science learning (Feinstein & Kirchgasler, 2015). STEM is a discipline that is closely related. Science requires mathematics as a tool in data processing, while technology and engineering are applications of science. STEM is expected to produce meaningful learning for students through the systematic integration of knowledge, concepts, and skills. Some of the benefits of the STEM approach make students can solve problems better, innovators, inventors, independent, logical thinkers, and technological literacy (Stohlmann et al., 2012).

Problem Based Learning (PBL), when integrated with STEM (Science, Technology, Engineering, Mathematics), will challenge students to thinking by presenting surrounding problems that can be related to technology, engineering, and mathematics. STEM will provide a learning experience that includes practice, engineering, and technology design that requires of science and concepts. Students will work collaboratively by engaging in problem-solving, making assessments investigations, and reflecting. Problem-Based Learning-STEM can increase students' interest in learning into meaningful learning, critical thinking skills, analysis and improve higher-order thinking skills in students (Afriana et al., 2016). The application of STEM-Problem Based Learning is very suitable to trigger students to think critically. According to Nasr & Ramadan (2008), Problem Based Learning-STEM can help students to think critically, especially when the problems are related to the real world.

Several researched have been carried out to determine the effectiveness of the Problem Based Learning-STEM. For example, Hapiziah et al. (2017) said that students' conceptual understanding of using Problem Based Learning-STEM is better than a student that does not use Problem Based Learning-STEM on reaction rate material. The purpose of Implementing STEM-Problem Based Learning strategy is to determine differences in students' conceptual understanding and critical thinking skills on learning chemical equilibrium (Ellizar et al., 2019).

II. Method

The design that used in this research is quasi experimental factorial design 2 x 2 in two groups. The samples are students of class XI SMA Negeri 2 Batu. The sample taking was based on convenience to access by the researcher. One class became the Experimental Group that learned using Problem Based Learning-STEM, and the other class became the Control Group that learned using Problem Based Learning only. The design of the research to be used shown in Table 1.

Table 1. Design of Research Quasy Experimental Factorial Design 2 x 2

Initial Ability	**Learning Strategy**	
	i PBL-STEM (X_1)	iPBL (X_2)
High (Y_1)	X_1Y_1	iX_2Y_1
Low (Y_2)	X_2Y_2	iX_2Y_2

Information:

- X1Y1: Students' conceptual understanding and critical thinking on Problem Based Learning-STEM with high initial ability
- X1Y2: Students' conceptual understanding and critical thinking on Problem Based Learning-STEM with low initial ability
- X2Y1: Students' conceptual understanding and critical thinking on Problem Based Learning with high initial ability
- X2Y2: Students' conceptual understanding and critical thinking on Problem Based Learning with low initial ability
- The instrument that used in this research include a conceptual understanding test and a critical thinking test. The prerequisite analysis test (normality and homogeneity test) of research data did before.

III. Results and Discussion

This research uses a moderator variable that is students' initial ability, which was obtained from the test value data on the previous material, reaction rate. Data recapitulation of students' initial ability showed in Table 2.

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Table 2. Data Recapitulation of Students' Initial Ability

Group	Average of Rate Reaction Test	Highest Score	Lowest Score	Group of Initial Ability	Number of Students	Total of Students
Experimental	78,75	100	55	High	26	36
				Low	10	
Controli	74,86	100	60	High	18	36
				Low	18	

Prerequisite test done by normality and homogeneity test. Results of normality students' initial abilities, the maximum L_{count} of both classes was less than L_{table} (0,126<0,148 and 0,147<0,148). Results of homogeneity test, the F_{count} is smaller than the F_{table} (1,221<4,130). In conclusion the data were distributed normally and homogeny. By obtaining data that is normally distributed and a homogeneous population variant, it can be continued to the hypothesis testing stage using the two-tail t-test.

Based on the results of the two-tail t-test on the similarity of the average students' initial ability, the t_{count} is smaller than the t_{table} (1,360<1,994), so that H_o is accepted with a significance of 5%. That concludes the students in the experimental and control classes have the same initial ability. Table 2 shows that students in the experimental class had an initial ability score with an average of 78,75, that 26 students with high initial abilities and 10 students with low initial abilities.

A. Students' Conceptual Understanding

The students' conceptual understanding after learning was obtained from the results of the students' conceptual understanding test at the end of the lesson. The instrument that used was a multiple choice.

Table 3. Result of Students' Conceptual Understanding Test

Group	Total of Students	Average of Conceptual Understanding
Experimental	36	84,87
Control	36	77,77

The prerequisite test is done by normality and homogeneity test. Results of normality students' conceptual understanding, the maximum L_{count} of both classes was less than L_{table} (0,142<0,148 and 0,147<0,148). Results of homogeneity test, the F_{count} is smaller than the F_{table} (1,031<4,130). In conclude, the data were distributed normally and homogeny.

This research used a moderator variable that is students' initial ability, so data of students' conceptual understanding were grouped again based on the students' initial abilities. The experimental class and control class are divided into groups of students with high and low initial abilities. Results of students' conceptual understanding test based on initial abilities showed in Table 4. The results of students' conceptual understanding are normally distributed and a homogeneous population variant. It can be continued to the hypothesis testing stage using the Two Way Anova, which showed in Table 5.

Table 4. Result of Students' Conceptual Understanding Test based on Initial Ability

Group	Group of Initial Ability	Number of Students	Average of Conceptual Understanding	Highest Score	Lowest Score
Experimental	High	26	86,04	100	56
	Low	10	82,30	100	44
Controli	High	18	83,16	100	78
	Low	18	72,24	89	56

Table 5. Result of Two Way Anova to Students' Conceptual Understanding Test

Impacti	F_{count}	Sig	Information
Learning Strategy	9,684	0,003	H_1 accepted
Initial Ability	17,655	0,000	H_1 accepted
Learning Strategy* Initial Ability	3,789	0,056	H_1 rejected

Table 4 shows that the average of students' conceptual understanding in experimental class with students' high initial abilities was 86,04, and students' low initial abilities was 82,30. Meanwhile, the average of students' conceptual understanding in control class with students' high Initial abilities was 83,16 and students' low initial abilities was 72,24.

Table 5 shows that the Two Way Anova hypothesis test to students' conceptual understanding based on initial abilities, there are 3 hypotheses, that are (1) The impact of learning strategy on students' conceptual understanding has a significance value = 0,003<0,05 so H_1 is accepted with the conclusion that there are differences students' conceptual understanding in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy, (2) The impact of initial ability on students' conceptual understanding has a significance value = 0,000<0,05 so H_1 is accepted with the conclusion that there are differences students' conceptual understanding based on initial abilities in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy, (3) The interaction between initial abilities and the learning strategy on students' conceptual understanding has a significance value = 0,056>0,05 so H_1 is rejected with the conclusion there are no interaction of Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' conceptual understanding.

B. *Critical Thinking*

The students' critical thinking after learning was obtained from the results of the students' critical thinking test at the end of the lesson. The instrument that was used was an essay question.

Table 6. Result of Students' Critical Thinking Test

Group	Total of Students	Average of Critical Thinking
Experimental	36	85,74
Control	36	80,83

Prerequisite test done by normality and homogeneity test. Results of normality students' critical thinking, the maximum L_{count} of both classes was less than L_{table} (0,132<0,148 and 0,142<0,148). Results of homogeneity test, the F_{count} is smaller than the F_{table} (2,001<4,130). In conclusion, the data was distributed normally and homogeny. This research using a moderator variable that is students' initial ability, so data of students' critical thinking were grouped again based on the students' initial abilities. The experimental class and control class are divided into groups of students with high and low initial abilities. Results of students' critical thinking tests based on initial abilities showed in Table 7.

Table 7. Result of Students' Critical Thinking Test based on Initial Ability

Group	Group of Initial Ability	Number of Students	Average of Conceptual Understanding	Highest Score	Lowest Score
Experimental	High	26	86,27	100	67
	Low	10	85,90	100	73
Controli	High	18	84,53	100	73
	Low	18	81,44	93	60

Table 7 shows that the average of students' critical thinking in experimental class with students' high initial abilities was 86,27, and students' low initial abilities were 85,90. Meanwhile, the average of students' critical thinking in the control class with students' high initial abilities was 84,53, and students' low initial abilities were 81,44. The results of students' critical thinking are normally distributed and a homogeneous population variant. It can be continued to the hypothesis testing stage using the Two Way Anova, which showed in Table 8.

Table 8. Result of Two Way Anova to Students' Critical Thinking Test

Impacti	F_{count}	Sig	Information
Learning Strategy	**4,289**	**0,042**	**H_1 accepted**
Initial Ability	5,774	0,019	H_1 accepted
Learning Strategy* Initial Ability	1,001	0,321	H_1 rejected

Table 8 shows that the Two Way Anova hypothesis test to students' critical thinking based on initial abilities, there are 3 hypotheses, that are (1) The impact of learning strategy on students' critical thinking has a significance value = 0,042<0,05 so H_1 is accepted with the conclusion that there are differences students' critical thinking in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy, (2) The impact of initial ability on students' critical thinking has a significance value = 0,019<0,05 so H_1 is accepted with the conclusion that there are differences students' critical thinking based on initial abilities in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy, (3) The interaction between initial abilities and the learning strategy on students' critical thinking has a significance value = 0,321>0,05 so H_1 is rejected with the conclusion there are no interaction of Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' critical thinking.

C. *Students' Conceptual Understanding*

The differences in students' conceptual understanding can be seen from the average of students' conceptual understanding test, there are 84,87 for experimental and 77,77 for control class. That is because in the experimental class, class that used Problem Based Learning-STEM, students are given a video about chemical equilibrium in the industrial, which is the Urea Fertilizer Industry. This video aims to show students that the application of chemical equilibrium can be utilized in a large field (factory) so that the product can be maximized (especially with the STEM approach), so that students' conceptual understanding of chemical equilibrium is better.

The integration of technology and engineering aspects in chemistry learning can encourage students to be better concepts and make the learning process more meaningful. This statement is relevant by several researchers, including Cantrell et al. (2006) which states that the integration of engineering aspects into learning materials can help students develop conceptual material and critical thinking skills. Rehmat (2015) states that engineering and technology help deepen students' conceptual understanding and achievement of grades. Hapiziah et al (2017) also said that the learning outcomes of students using Problem Based Learning-STEM teaching materials were better than the learning outcomes of students who did not use Problem Based Learning-STEM materials. Sa'adhah (2019) said that the STEM learning strategy could be used as an alternative learning strategy to increase student activity and learning outcomes.

D. Critical Thinking

The differences in students' critical thinking can be seen in the average of students' critical thinking test, and there are 85,74 for experimental and 80,83 for control class. That is because in the experimental class, the class that used Problem Based Learning-STEM, there is an integration of STEM aspects. The STEM aspects include science as a process, technology as the application of science, engineering as engineering science, and mathematics as a tool. STEM in the Problem Based Learning strategy will bring students closer to real life, that is problems that exist in the environment that can be raised for learning (Wang, 2009). STEM integration focuses not only on content, but also incorporates problem-solving skills as well as inquiry-based instruction.

Science is a process, which students are guided to observe, ask, try, associate, and communicate a phenomenon that occurs in everyday life. Technology as the application of science, which students are given several examples of the application of chemical equilibrium in the industrial, which manufacture of ammonia according to Haber-Bosch, manufacture of sulfuric acid through the contact process, and manufacture of nitric acid, which aims to facilitate students in understanding technology related to factors that can influence on chemical equilibrium. Engineering as engineering science and mathematics as a tool, where students are invited to count using the mathematical formula that is in the material being studied.

This research is relevant to several researchers, including Sukmana (2018) said that the implementation of learning using the STEM approach influences increasing students' critical thinking skills. In addition, research by Khoiriyah et al (2018) also said that learning with the STEM approach can significantly improve students' critical thinking skills with a 95% confidence level and an N-gain value of 0,63 in the moderate category. Based on the description above, it can be concluded that the integration of STEM in learning can improve students' critical thinking skills.

The results of the hypothesis of students' conceptual understanding show that the F_{count} is 17,655, while F_{table} is 3,982. That shows that $F_{count} > F_{table}$, which H_1 is accepted, and H_o is rejected, and hypothesis of students' critical thinking shows that F_{count} is 5,774, while the F_{table} is 3,982. That shows that $F_{count} > F_{table}$, which H_1 is accepted, and H_o is rejected.

Table 9, it shows that students with high initial abilities got a higher average students' conceptual understanding and critical thinking than students with low initial abilities. Students with high initial abilities also have high curiosity, so that they play an active role during learning activities to find out various new information that is related to their initial abilities. Students with low initial abilities tend to rely on other friends to complete their tasks because they have minimal initial abilities that related to the material being studied, so they become passive during learning activities.

Table 9. Data Recapitulation of Students' Conceptual Understanding and Critical Thinking based on Initial Ability

Initial Ability	Conceptual Understanding	Critical Thinking
High	84,60	85,40
Low	77,27	83,67

The results of hypothesis of students' conceptual understanding show that the $F_{count} < F_{table}$ is 3,789<3,982 with a significance = 0,05. That shows that H_1 is rejected, so it can be concluded that there is no interaction of Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' conceptual understanding of fundamental of chemical equilibrium on XI SMA Negeri 2 Batu and the results of hypothesis of students' critical thinking show that the $F_{count} < F_{table}$ is is 1,001<3,982 with a significance = 0,05. That shows that H_1 is rejected, so it can be concluded that there is no interaction of Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' critical thinking in fundamental of chemical equilibrium on XI SMA Negeri 2 Batu.

This research shows that the learning strategy and students' initial abilities do not influence each other. That happens because the Problem Based Learning-STEM strategy and the Problem Based Learning strategy provide opportunities for students to be more active and independent in the learning process so that students have the freedom to develop activities in finding concepts, identifying, and solving problems so that students can work actively in groups and will improve their conceptual understanding and critical thinking in their respective initial abilities. Therefore, the learning strategy and initial ability do not significantly influence students' conceptual understanding and critical thinking.

IV. Conclusion

Based on the result of research, there are differences students' conceptual understanding and critical thinking in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy. Besides that, there are differences students' conceptual understanding and critical thinking based on initial abilities in the group that learned by Problem Based Learning-STEM with the group that learned using Problem Based Learning strategy. But there no interaction between Problem Based Learning-STEM strategy and Problem Based Learning based on initial abilities to students' conceptual understanding and critical thinking.

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