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Article

The Implementation of Problem Based Learning Model With STEM (Science, Technology, Engineering, Mathematics) Approach to Train Students' Science Process Skills of XI Graders on Chemical Equilibrium Topic

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ABSTRACT

This study aims to determine the improvement of learning outcomes and students' science process skills by implementation PBL (Problem Based Learning) model with STEM (Science, Technology, Engineering, Mathematics) based on chemical equilibrium topic. The method in this research is quantitative descriptive with One-Group Pretest-Posttest design. The subjects of this study were students of Mathematics and Natural Sciences XI graders in State Senior High School 1 Pulung, Ponorogo Regency. Data method is; observation, questionnaires, and tests. Technical data analysis used is; analysis of study results data, analysis of observations of learning implementation, analysis of student activities, analysis of learning outcomes completeness, and analysis of student responses. The results in this study were: (1) the mean percentage of the implementation of PBL model based on STEM in the chemical equilibrium topic was 89.26%; (2) the category of improvement for all indicators of Science Process Skills observing and conclusion that respectively 0.82 and 0.89 are included in the high category, for the skills to formulate problems, formulate hypotheses, determine variables, and analyze data respectively of 0.64 ; 0.42; 0.67; 0.68 and can be categorized as moderate; (3) the learning outcomes of students in the realm of knowledge have increased classically with n-gain of 0.62 in the moderate category; and the last (4) learning by implementation the STEM-based PBL model on chemical equilibrium material received a positive response from students based on the results of the questionnaire, the percentage was 83%.

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INTRODUCTION

Technology is increasingly experiencing rapid changes, making the learning process and objective experience a lot of shifts, especially in the current digital era which is experiencing changes in people's in behavior that demands fast and practical. The demands of the world of education for educational processes and outcomes have also changed. In human life, education is very important and determines its survival. Without education, human beings do not have the manners, ethics, skills, or other life skills to help them succeed. The world of education is not only required to produce humans who understand science, but more than that, to produce humans who are able to contribute to solving problems faced by humans, both those concerning social life, natural resources, environmental sustainability and so on. Therefore, the government's effort to improve the quality of education is through the 2013 curriculum. This curriculum is a breakthrough that is made to continue to seek the best options in the delivery of education in Indonesia.

According to the Ministry of Education and Culture (2013), the 2013 curriculum mandates the scientific essence (scientific approach) in learning because this approach is believed to be able to develop the attitudes, skills and knowledge of students. Learning that is currently developing requires students to have proficiency in various things. The ability to think critically is something that must be honed by using scientific-based learning. It is undeniable that in an era of disruption, which is all instantaneous, fast, and complex, students must be able to use technology in learning and be able to adapt quickly. The scientific approach to learning is carried out to foster positive attitudes in students as stated in (Kemendikbud, 2013), namely: observing, asking, processing, presenting, and creating.

Learning in Indonesia has a gap between expectations and reality. In the rules that have been made, students should be evaluated in the high-level cognitive domains, such as analyzing, evaluating, and creating. However, the current evaluation only focuses on low-level cognitive abilities, namely memorizing and understanding concepts. This can be seen in the national examination questions as well as in each semester and mid-semester evaluation.

High school level education has several science-based learning subjects. One of the subjects, is Chemistry. This subject provides students with experiences related to practical matters both in the classroom and in the laboratory. Students have an interest in new things through the science method directed by the teacher. Student activeness is the responsibility of the teacher, so learning must be set as attractive as possible. The teacher provides facilities to students in developing science process skills. These skills must be mastered by students in relation to the implementation of science learning actions that create concepts, principles, theories, and laws from facts (Ozgelen 2012). Science process skills are a product of learning in developed countries which are included in the curriculum (Toplis and Allen, 2012). In the development of the curriculum in Indonesia, every successness that developed countries have in education will become a portrait for developing the latest curriculum.

Chemical equilibrium material is one of the materials that students felt so difficult. This was evidenced by several student learning outcomes that were not satisfactory, and this was supported by the statement of the results of interviews with teachers from State Senior High School 1 Pulung, Ponorogo that 50% of students did not complete the equilibrium material. This basic competency expected from the material of chemical equilibrium 3.9 that is

analyzing the factors that affect the shift in direction and its application in industry and basic competencies 4.9 that is designing, conducting, and concluding as well as shifting the direction of equilibrium (Kemendikbud, 2016)

Student process skills can be implemented with several learning models, one of that model is Problem Based Learning. The phases of PBL model are (Trianto, 2007): (1) student-oriented problems; (2) students organized to research; (3) the sorting of students being guided; (4) student work in presenting and developing, and (5) the problem-solving process is analyzed and evaluated. The ability to analyze and manage information will be trained for students, so that they can learn independently and be able to solve problems (Suprijono, 2009). The PBL learning model is way that can help student master the concepts of a subject based on problems in real life (Depdiknas, 2008). PBL model can make students think to solve problems in real world context. This model has advantages, namely students get more lessons from problems in real life and are stimulated to solve them. This will be useful when they graduate and the more experience they have in solving problems in their environment, it is hoped that students' thinking concepts will be more mature.

One of the materials taught in grade IX in odd semesters is chemical equilibrium. In his study, using the 2013 curriculum as reference for basic competencies, namely KD 3.9 analyzes the factors that affect the shift in the direction of equilibrium and application in industry and KD 4.9 designing conduct concluding and presenting the result of the experiment of the factor that affect the shift in the direction of equilibrium. Based on these basic competencies, with phenomena in everyday life. In the implementation of this research, the STEM approach and the PBL model will encourage students to be independent in the learning process and direct student to be able to solve daily in life.

The PBL model combined with Science, Technology, Engineering, and Mathematics (STEM) approach is considered to be in accordance with the current curriculum. PBL model with STEM approach is able to direct students to independently solve problems with scientific concepts and be able to take advantage of technology in everyday life. This learning concept provides space for students to carry out scientific engineering to provide solutions to the problems at hand. STEM learning provides students with a scientific experience to innovate in learning and solving problems (Corlu, 2014). This reinforces this research that PBL combined with STEM will provide interesting solutions in student learning activities, especially chemical equilibrium material. In addition, this is reinforced by statement of Nafiah (2014) which states that with PBL, students gain learning experiences by communicating, collaborating, formulating ideas and fostering reasoning skills.

Based on the background of the problem above, the researcher formulated the problem in this study, namely: 1) How is the implementation of the PBL model with STEM approach in the chemical equilibrium material?; 2) How are the students' science process skills after implementation the PBL model with STEM approach to the chemical equilibrium material?; 3) How are the students' learning outcomes classically after implementation the PBL model with STEM approach to the chemical equilibrium material?; and the last 4) How do students responds to the learning process by implementation the PBL model with STEM approach on chemical equilibrium material?

METHOD

This research was conducted from November 2 to 23, 2020. This type of research is quantitative descriptive research by describing a variable systematically, facts, and accurately through data collection techniques in the form of field observations, and working on Students' Work sheet using the STEM approach, described systematically, factually, and accurately about the application of the PBL model based on the STEM approach. This study has a research design, namely One-Group Pretest-Posttest with this design, there is one class without a comparison group. Given the pretest to see the initial state, the expression is given a posttest. The test was presented in the form of multiple choice questions. This test was carried out before the pre-test (pretest) and after the final (posttest) learning model of PBL on chemical equilibrium material.

The procedure in this study has 3 stages of the procedure taken including, a) Preparation stage: preliminary study (pre-research), literature study, curriculum review, mapping of Core Competences and Basic Competences, making and compiling research instruments, validation, and testing ; b) Implementation stage: Preliminary test (pretest) and implement learning with PBL model based on STEM approach; c) The final stage: the final test (posttest) and giving a questionnaire. The subjects of this study were students of grade XI of Mathematics and Natural Sciences Students in State Senior High School 1 Pulung, Ponorogo Regency. Quantitative data methods in this study, is: observation methods, questionnaire methods, and test methods. The instruments in the study included: learning implementation sheets, student activity sheets, learning outcomes assessment sheets, and student response sheets. The data analysis techniques used in this study are as follows: analysis of study data, analysis of learning implementation observations, analysis of student activities, analysis of learning outcomes completeness and analysis of student responses

RESULTS AND DISCUSSION

Implementation of the PBL Model with STEM Approach in Chemical Equilibrium Material

The suitability of the activities carried out by the student during the learning process with the phases of the PBL model became a benchmark for the feasibility of the PBL model. Observation sheet for feasibility observation to measure the implementation of syntax in the learning process for students. The phases of implementation of the learning model can be said to be good, if it is in the good or very good category with a percentage of $\geq 61\%$ of 100% (Riduwan, 2015). The following figure was a graph of the results of the implementation obtained in Figure 1.

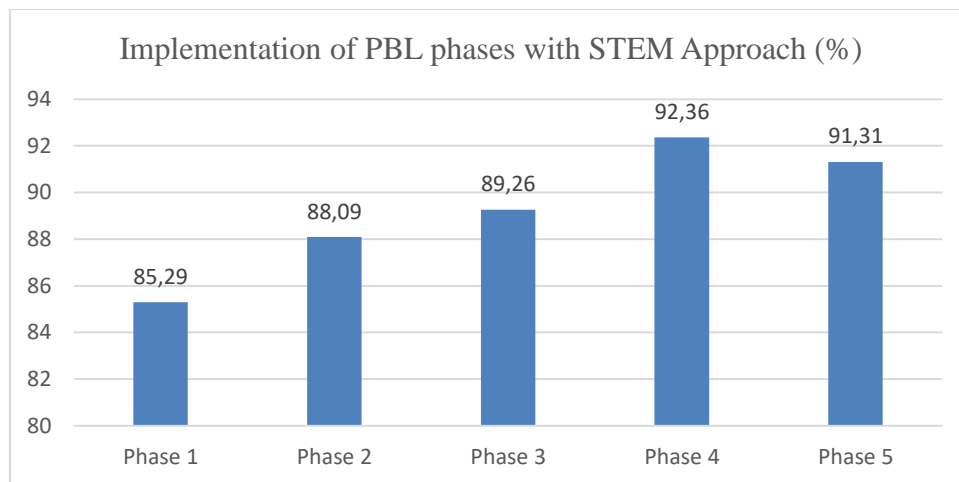


Figure 1. The results of the implementation of each PBL phases during learning

Based on figure 1, each phase in PBL obtained a percentage of 85.29% for (1) the orientation of students on the problem; for phase (2) organizing students to learn, the percentage of implementation was 88.09%; then phase (3) guiding individual and group investigations, the percentage was 89.26%; phase (4) developing and presenting the work obtained a percentage of 92.36%; and the last phase (5) analyzing and evaluating the problem-solving process, it was obtained 91.31%. The five phases got a percentage of $\geq 61\%$, which can be concluded that the implementation of PBL was in the very good category (81% -100%) for each phase in PBL and the average of all phases was 89.26% and include in the very good category (81% -100%)

The percentage of each phase has a difference in results, from phase 1 to phase 5. The phase that got the greatest percentage results was the 4th phase that was 92.36%, this was because in this phase the dominant activity of all students were done in this phase. Phase 4 was the stage where students can develop and present the work that has been made, the role of the teacher here was only as a facilitator. In addition, PBL also prioritized the learning process, so the teacher's job was only to focus on helping students to achieve skills (Nafiah, 2014). This was in line with Ngalimun's statement (2013) which states that PBL is a learning model that involves students to solve a problem through the stages of the scientific method so that students can learn knowledge related to the problem and at the same time have the skills to solve problems.

In phase 4 played a very active role both in the process of making work until later presenting their work in accordance with the STEM approach used, in accordance with Bybee's (2011) statement that by including STEM in learning, knowledge, attitudes, and skill student and increase in identifying problems and formulating questions according to life, explaining phenomena that occur. The STEM components used in this study are as presented in table 1.

Table 1. STEM Components that used in this Research

Science	Technology	Engineering	Mathematics
1. Analyze the effect of the equilibrium factor on a phenomenon	1. Creating a simulator as a visualization of the concept of factors that affect chemical equilibrium	1. Manufacturing NH_3 Haber Bosch 2. Proses Haber Bosch. <i>Link: https://www.youtube.com/watch?v=tSc3SHiG3is</i> 3. Preparation of sulfuric acid by contact process 4. Proses Kontak. <i>Link: https://www.youtube.com/watch?v=XN42nQqlomE</i> 5. The process of making nitric acid with the Ostwald process 6. Pembuatan Asam Nitrat melalui Proses Ostwald. <i>Link: https://www.youtube.com/watch?v=vs4GU7jfQb0</i> 7. Make a presentation to present the results of making a simulator tool in the form of a video or PPT	Chemical equilibrium constant 1. Calculating K_p 2. Calculating K_c 3. Calculate the degree of dissociation
2. Develop experimental hypotheses			

In addition, the results of this implementation were also supported by the results of student activity data in Figure 2.

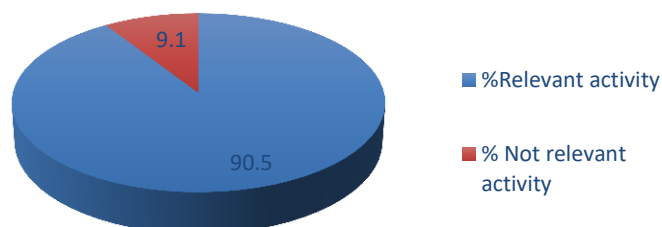
**Figure 2.** The results of student activities during learning

Figure 2 showed the results of the average percentage of student activity during learning from the 1st meeting to the 3rd meeting. These results indicated that during learning, the majority of all students activities were relevant and in accordance with the stages in the PBL model. The average percentage is 90.5% while for activities deemed less relevant it was 9.1%. Student activities that were said to be relevant and well implemented well so that student can design students can designed their own experiments and recorded the results of the experiments in the student worksheet provided, then student were also actively involved in showing and writing on the board the results of calculating chemical equilibrium provisions. In addition, students in their respective groups were also actively discussing and

gathering information from each other. In accordance with the concept of STEM integration in PBL, that working in groups can encourage students to work together but are still responsible for their work independently (Ma & Ma, 2014). PBL will be integrated between the concepts of science, technology, engineering and mathematics in developing student creativity through the process of solving daily problems (Utami, 2017)

While examples of student activities that were said to be irrelevant were found activities that disturb other friends who were studying, there were those who did not pay attention to the teacher during learning and so on which were not in accordance with student activities in the learning stage with the STEM-based PBL model on this chemical equilibrium material.

Student Learning Outcomes in the Realm of Students' Science Process Skills After the Implementation of the PBL Model with STEM Approach in the Material of Chemical Equilibrium

This research that has been done using science process skills as proposed by Chang (2008). The indicators used in this study were shown in table 2 as follows.

Table 2. Indicators of Science Process Skills

Science Process Skills	Indicator
Observe	<ol style="list-style-type: none"> 1. Identify common characteristics and groups of things 2. Identify the different characteristics 3. State the relationship that occurred 4. Make scientific questions
Formulate problems	<ol style="list-style-type: none"> 1. State the relationship that occurred 2. Make scientific questions
Make a hypothesis	<ol style="list-style-type: none"> 1. Identify the manipulation variables and the response variables 2. Determine the relationship between two variables
Controlling variables	<ol style="list-style-type: none"> 1. Determine the relevant variables in the investigation 2. Determining constant, manipulation, and response variables 3. Determine the appropriate action on the variable being manipulated
Analyzed and Interpret the Data	<ol style="list-style-type: none"> 1. Using scientific knowledge and understanding to explain and interpret observations, measurements in data 2. Explain if one of the variables does not exist

Based on the indicators in table 2, the following showed the pretest and posttest results obtained for each Science Process Skills indicator in Figure 3.

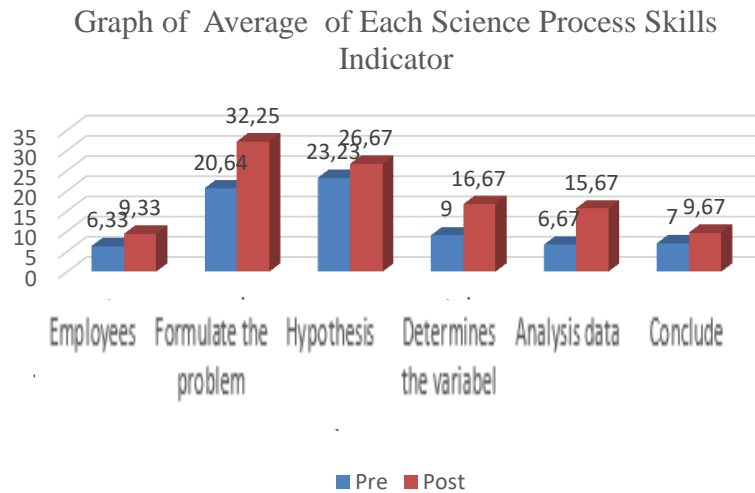


Figure 3. Pre and Post Science Process Skills indicator

After obtaining the pre-post data graph of each Science Process Skills indicator according to Figure 3 above, the increase can be seen through the n-gain score (Hake, R, 1998) with the following formula.

$$N - gain = \frac{skor\ posttest - skor\ pretest}{skor\ maksimal - skor\ pretest}$$

Based on the calculation formula above, the results were obtained according to Figure 4 below.

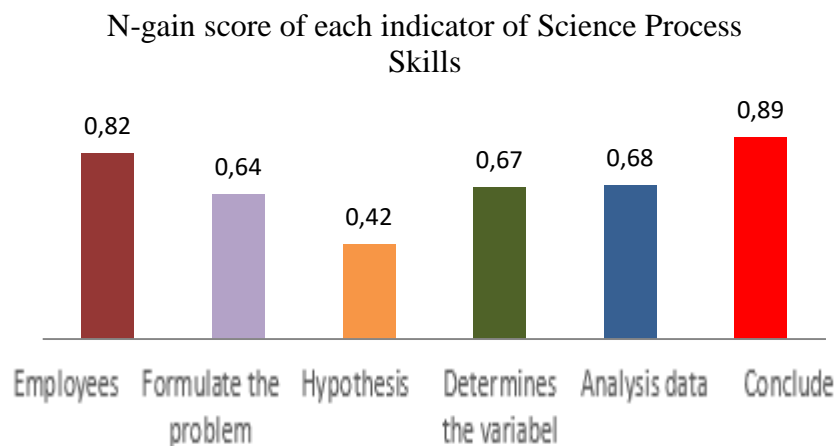


Figure 4. N-gain score for each science process skills indicator

Based on Figure 4, each indicator of Science Process Skills has increased from the pretest to posttest results. The N-gain score of each indicator showed a significant result so that it can be categorized under the N-gain criterion that if $g \geq 0.7$ then the category of increase is high, whereas if $0.3 \leq g \leq 0.7$ then the category was medium, and if $g \leq 0,3$ then the category was said to be low. From the results obtained, on figure 4 the categories of improvement for observing and concluding skills are 0.82 and 0.89 respectively, so it was

included in the high category, for the skills to formulate problems, formulate hypotheses, determine variables, and analyze data, respectively. 0.64; 0.42; 0.67; 0.68 and can be categorized as moderate.

The n-gain results above indicated that all Science Process Skills indicators that are trained to students through tests of science process skills with multiple choice questions of chemical equilibrium material can be said that have increasing. The science process skills to observe and conclude were in the high category. This was because most students were familiar with both observing and concluding skills. We knew that observing skills were the most basic Science Process Skills in the scientific method (Qomariyah, 2014). In observing skills students used more than one of their senses in identifying general characteristics and groups of things. Likewise, the Science Process Skills concluded that it was also included in the increase in the high category. In concluding, students stated whether the hypothesis can be accepted or rejected by providing the right reasons. In addition, they must also consider whether the evidence gathered was sufficient for any conclusion (Sudjana, 2008). Based on these results and notes in the field, indeed the skill of observing and concluding can be in the high category because when learning students do not find it difficult, this Science Process Skills also a basic of Science Process Skills and was often trained in solving scientific concepts.

For the skills to formulate problems, formulate hypotheses, determine variables and analyze data improvement research belong in the medium category. Before formulating a problem, students will observe the phenomena that presented by the teacher. Then make new observations students can ask scientific questions in the form of problem formulations based on the phenomena that have been observed (Kheng, 2008). However, there are some students here who were still having difficulties. They still need to be guided on how to formulate a problem in a question sentence. The purpose of Science Process Skills was to formulate the problem itself, namely, by asking questions. It gives students space to express what they want to know.

In Science Process Skills of making hypotheses, not all students were immediately said to be able to in this skill. The teacher at that time was still directing and guiding them, because it was closely related to the previous Science Process Skills, namely formulating problems, so that if the problem formulation was still not appropriate, the ability to formulate hypotheses would still experience difficulties. In accordance with the statement (Toplis and Allen, 2012), the hypothesis is conjectural which can be a temporary answer because it is necessary to prove it first to find out the truth. In stage before do the problem formulation of the given phenomenon so that student can describe the hypothesis and show the causal relationship between the two variables, namely the manipulation and response variables.

After the hypothesis can be made, students should also be trained in determining variable skills. This process skill teaches students to determine interrelated variables in an investigation, so that this skill is considered very important in learning, especially in carrying out scientific investigations Tanwil (2014) However, based on data obtained from the Science Process Skills test results, not all students have mastered the skills to determine this variable. The problem was that there were some students who did not understand what the variable was, and some were not even able to distinguish between the manipulation, control and response variables.

The next Science Process Skills was included in the medium category, namely analyzing data, as well as the skills that have been discussed earlier. The obstacle in practicing Science Process Skills was that students were not familiar with problems that require analysis skills. Amnie, et al. (2014) said that in this skill students should be able to use their knowledge to explain and interpret the results of observations and measurements, then analyze the data obtained when conducting experiments. In addition, students explain if the variables are used. So it can be said in this study, data analysis skills are still in the category of being improved.

Student Learning Outcomes in the Domain of Students' Knowledge After the Implementation of the PBL Model with STEM Approach on Chemical Equilibrium Material

The completeness of the cognitive learning outcomes of students was used to determine the learning outcomes of students in the cognitive domain. The goal of achieving equilibrium material includes students being able to understand: (1) the effect of concentration on the shift in the direction of equilibrium (2) the effect of temperature on the shift in the direction of equilibrium (3) the effect of volume and pressure on the shift in the direction of equilibrium (4) the effect of the catalyst on the shift in the direction of equilibrium.

There are general rules that help predict the direction a reaction will shift in case of changes in concentration, pressure, volume, and temperature. The proposed rule is known as the Le Chatelier's principle, which states that if an external pressure is applied to an equilibrium system then this system will adjust itself in such a way as to offset some of the stress when the system tries to balance again. "Pressure" is defined as a change in concentration, pressure, volume or temperature that shifts the system from an equilibrium state (Chang, 2005). To find completeness of cognitive learning outcomes was done individually. Student learning outcomes were said to be complete if they have the minimum score value ≥ 70 obtained from the pretest and posttest results. The increase in cognitive learning outcomes before and after the application of the PBL model was analyzed using the N-gain equation such as the calculation of the Science Process Skills test results previously discussed. The following was the learning outcome data in the cognitive domain of chemical equilibrium before and after learning with the PBL model with STEM Approach as shown in Figure 5.

Classical Cognitive Domain Pretest-posttest Results

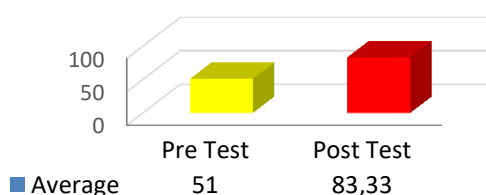


Figure 5. pretest and posttest results in cognitive domain

Based on the results obtained in accordance with figure 5, it showed that there was an increase classically from the pretest and posttest results so that the n-gain value was 0.62 and can be said to be in the moderate category. The average posttest result can also be known as 83.33, which means that the learning outcomes of students were said to be complete because they have met the score minimum value ≥ 70 . In this study, the cognitive domain being tested was using the basic competencies in the domain of knowledge (KI.3) contained in the 2013 curriculum namely KD 3.9 which reads Analyzing the factors that influence the shift in the direction of equilibrium and its application in industry and KD 4.9 which says Designing, conducting and concluding, and presenting the experimental results of the factors that influence the shift in the direction of equilibrium.

Therefore, the purpose of giving a cognitive test on chemical equilibrium material was to increase their understanding and change the students' mindset that the chemical equilibrium material was not as difficult as they initially imagined.

With the existence of STEM-based PBL model, it can help them complete learning outcomes in the cognitive domain, especially this chemical equilibrium material. STEM-PBL learning provides motivation for students to create technological engineering to solve the problems that are presented. This was in line with the statement of Corlu (2014) which states that STEM-based education includes various disciplines of science in order to obtain comprehensive and relevant knowledge for life as a form of preparation for students with a mindset that can provide various innovations. The same thing was also expressed by Nafiah (2014), that through PBL students gain experience in dealing with realistic problems and emphasize the use of communication, cooperation, and existing resources to formulate ideas and develop reasoning skills.

Student Response to the Learning Process by Implementation of PBL Model with STEM Approach on Chemical Equilibrium Material

Student responses or opinions after implementing the STEM-based PBL model were a form of student response. After the application of the STEM-based PBL model, there was a response from students. Student responses were analyzed using the student response questionnaire sheet given at the last meeting with several questions that led to their questions related to increased interest in learning, activeness during learning, and how they understood their material after being given learning with this STEM-based PBL model. Student responses were said to be positive if $\geq 61\%$ of students have a positive response to the STEM-based PBL model to improve student learning outcomes on equilibrium material (Riduwan, 2015). The following was the results of the student response questionnaire as shown in Figure 6.

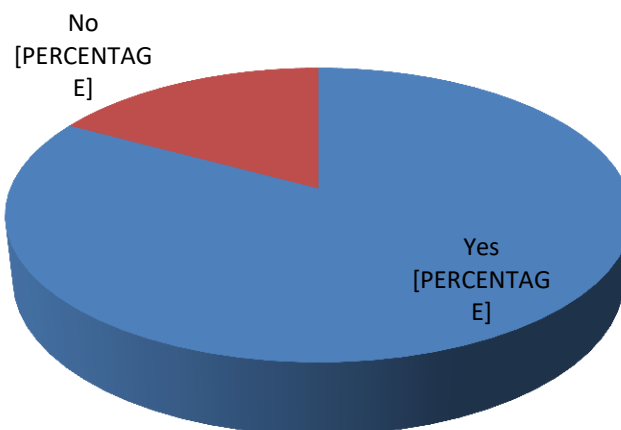


Figure 6. Student response questionnaire results

Based on Figure 6, it can be seen that the results of student responses with “Yes” answers was 83% and for “No” answers was 17%, which means that students have a positive response to the STEM-based PBL model to improve student learning outcomes on chemical equilibrium material. This was in line with the opinion of Glazer (2011), who argued that was teaching in which students were actively faced with complex problems and real situations. This opinion was in accordance with the conditions of students when learning takes place where they were faced with groups that were actively involved with each other, being able to learn from concepts that exist in the real world. STEM-based PBL, can stimulate the development of critical and creative thinking skills and comprehensively because in the learning process students carry out mental processes by investigating problems from various aspects / fields (Abbdudin, 2011) (Syukri, 2013)

CONCLUSION

Based on the background of the problem, theoretical studies as well as the results of research and discussion in this study, it can be concluded that (1) the STEM-based PBL model on chemical equilibrium material was carried out in a very good category with a mean percentage of 89.26%; (2) the learning outcomes of students in the realm of students' science process skills after the implementation of the PBL model with STEM approach on chemical equilibrium material, the results showed that the categories of improvement for observing and concluding skills were 0.82 and 0.89, respectively, including the high category, for skills in formulating problems, formulating hypotheses, determining variables, and analyzing the data for each of 0.64; 0.42; 0.67; 0.68 and can be categorized as moderate; (3) the learning outcomes of students in the realm of cognitive domain after the implementation of the PBL model with STEM approach on chemical equilibrium material have increased classically from the pretest and posttest results so that the n-gain value is 0.62 and can be said to be in the moderate category; and the last (4) learning by implementing the STEM-based PBL model on chemical equilibrium material received a positive response from students based on the results of the questionnaire, the percentage was 83%.

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