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# EFFECTIVENESS OF LEARNING MODEL IMPLEMENTATION STEM AND PROJECT BASED LEARNING TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS

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**ABSTRACT**

*This research aims to describe the process and results of developing a STEM learning model using the PjBL model to improve students' critical thinking abilities. This type of research is a combination method of the Concurrent Triangulation model which consists of step one, qualitative research using the learning development model proposed by Kemp 1994, while step two is quantitative research using quasi experimental design research. The implementation of the development of this model was carried out at SMA Negeri 8 Ternate City, North Maluku Province involving 64 students in class students in experimental class 2 PjBL Model. Critical thinking ability data was taken using a test instrument with a reliability of 0.76. Data analysis was carried out using the one way unequal Anova test. The results of the research show that there is no significant difference in critical thinking skills between the STEM learning model and the PjBL model on critical thinking skills on the subject of Indonesian natural resource management in the large category.*

**KEYWORDS** *STEM Learning Model, PjBL Model and Critical Thinking Ability*



## INTRODUCTION

National education goals include 21st century learning which is a new paradigm that makes students have the ability to search from various sources, problems and then formulate, think analytically, be able to work together to solve problems. According to Trisdiono, Indonesia in the 21st century currently has homework to do to adjust to the guidance of the times because the current state of Indonesia's human resources is not yet competitive. In addition, Tilaar said that to overcome this problem, one of the requirements is to improve the quality of education, such as indicators of the achievement of human resources that are able

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to compete in the current era is a teacher who is required to have competencies that are able to carry out his duties professionally. However, until now the conditions in the field are still lacking both in quantity, quality and professionalism of teachers.

This problem certainly adds to the burden on education organizers because in the future more complex challenges in today's global era cannot be avoided, Daryanto (2017: 3). 21st century learning, one of which is the STEM learning approach, according to Hanover in a Resarch said learning, Science, Technology, Engineering and Mathematics (STEM) in the 1900s was pioneered by Americans who wanted to innovate in education and spread the STEM approach with the aim of creating a workforce for the easy generation who will be skilled, knowledgeable in the field and able to compete in the global world and science and technology. Khairani et al, 2018: 106).

In addition to the STEM learning model approach, there is project-based learning which is not much different from the STEM learning approach because in fact these two lessons are student-centered, expected to be able to develop student skills, according to Gear in a book entitled 21st century learning says project-based learning or project and task-based learning, is able to explore the potential in students and can provide meaningful and interesting learning experiences for students, Daryanto (2017: 245)

Thus, geography is one of the subjects that can deliver students more practically and not abstractly in receiving material, namely through STEM learning approaches and project-based learning. In research conducted, Ningrum & Rahman 2022: 305) said that the application of science, technology, engineering, and mathematics (STEM) with distance learning (from home) with a project-based learning model (project and task learning can provide an increase in students' creative thinking skills and mastery of concepts in the material. Then the research conducted by Zayyinah et al, (2022: 256-257) said that project-based learning in implementing learning using a STEM or STEM-integrated approach has a very positive effect, because it can improve 21st century skills. This learning is able to provide learning experiences that exist in their lives, in real terms by linking to the concept of material by combining projects with the unity of these disciplines. This learning also provides opportunities for students to demonstrate 21st century skills which include critical thinking, creativity, knowledge processes, scientific literacy, communication and others. Thus this research was conducted to determine the effectiveness of the development of STEM learning models and project-based learning (PjBL) learning models.

## RESEARCH METHOD

This type of research is a Combination Method Concurrent Triangulation Method model which is a research method that combines qualitative or quantitative methods. Sugiyono (2018: 579). In this study, rare one Qualitative research in this study uses the learning development model proposed by Kemp 1994, while step two is quantitative research using *quasy experimental design* research. This study used the subjects of two classes, namely the Experiment class that received STEM learning treatment with the PjBL model, and the control class received conventional

learning treatment. Experimental and control classes each amounted to 24 students of XI IPS 1 and IPS 2 SMA Negeri 8 Kota Ternate, North Maluku Province. The learning treatment was carried out for 12 face-to-face meetings for each class with an allocation of 90 minutes per meeting. The measurement instrument used validated and reliable critical thinking skills test questions. Data analysis in this study used one-way unequal ANOVA and multiple comparisons, followed by Scheffe's Test. The formula used is the following formula;

$$\text{Jka} = \sum \frac{T2}{N} - \frac{G2}{N}$$

Description:
k = number of groups
T = total X of each group
G = overall total X
n = number of samples of each group
N = total sample size

Post Anova Test

$$F = \frac{(\bar{X}_i - \bar{X}_j)^2}{RK_S\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$$

Description:
$_{obs}$Fi-j/F= the F value of the i-th treatment and j-th treatment comparison;
$X_i$ = the mean of the i-th sample;
$X_j$ = average in the jth sample;
RKG = mean square error, which is obtained from the calculation of variance analysis;
$n_i$ = i-th sample size;
$n_j$ = jth sample size; Usmadi, (2014: 5)

## RESULT AND DISCUSSION

The result of the research is a process of developing a STEM learning model, PjBL model of lecture learning. based on the results of needs analysis in the field. From the analysis stage through interviews with teachers, information was obtained that a learning process was needed that was able to utilize technology to achieve learning objectives on the material of managing Indonesia's natural resources. Regarding the character of students, it is known that students are proficient in using technology and most students already have smartphones, laptops. The findings from the analysis stage are then followed up at the stage of the model development process which has adjusted to the steps of the STEM learning model and the PjBL

Model. To make it clearer below, it will be presented in accordance with the findings in the field. Then begins with the research data as follows:

**Research Result Data**

Table 1. Description of data on initial critical thinking ability of learning model class STEM, PjBL and Control

| Group | N | Min. | Max. | $\bar{X}$ | SD |
|---|---|---|---|---|---|
| Experiment 1 | 24 | 40,0 | 71 | 54,5 | 8,2 |
| Experiment 2 | 24 | 36,4 | 67,3 | 50,1 | 8,8 |
| Control | 20 | 34,55 | 67,2 | 48,73 | 10,24 |

Based on Table 1. it is known that the initial ability of critical thinking of students is still low. It is known that the average obtained by the experimental group I experiment II and the control class, the average obtained ranges from 30.55 to 39.5 with the acquisition of values 42 to 58. The range of sandtar deviation is 7.8 to 12.3. Thus these results can be seen in Figure 1 graph.

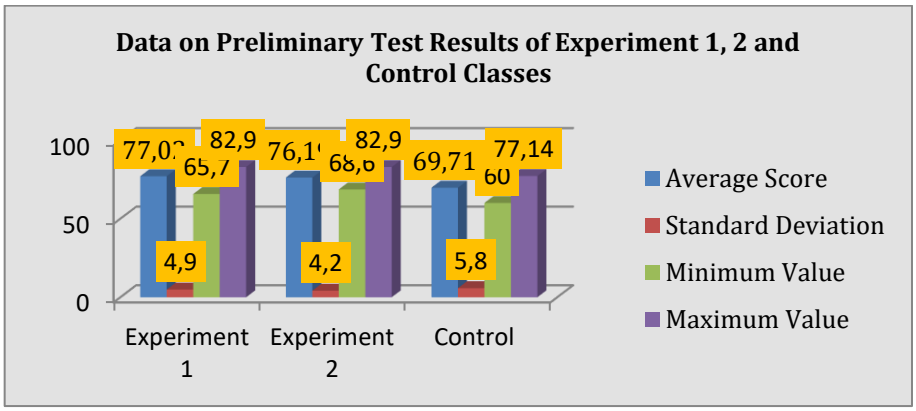


Figure 1. The results of the initial data description of the ability to think critically

**Data from the post pre-test instrument test**

***Validity Test and Reliability Test***

In this study there were 55 questions that were made based on the question grid. To determine the level of validity of a question, a calculation is made based on the score in each question item and then calculated as an example if the calculated r value is greater than the r table, then the question is said to be valid but otherwise the question is said to be invalid, and the question can be used or discarded. In other words, to find out the measuring instrument such as the questions in the questionnaire, to ensure that it is valid, it needs to be measured so that it can reveal the questionnaire, (Nilda Miftahul 2021). Furthermore, the relibaelitas test stage is one of the tests that can be used by the measuring instrument to remain consistent if repeated measurements are made, (Nilda Miftahul 2021). And the reliability test can be seen in the table below:

Table 2.Reliability Test

| Basis for Decision Making | |
|---|---|
| Reference Value | > 0,70 |
| *Cronbach's Alpa* Value | 0,76 |
| Conclusion | Reliable |

Source: Primary Data

Based on table 2. It can be seen that the reference value is 0.70 and the Cronbach's Alpa value is 0.76, it can be concluded that the question is said to be reliable and the test questions can be used to carry out research tests.

**Analysis Prerequisite Test Results**

***Normality test of initial ability normality test paca treatment STEM learning model, PjBL and Conventional model (Lecture)***

Normality test is one of the prerequisite tests that must be met before conducting variance analysis. The normality test is carried out to determine whether the samples used in the study come from a normally distributed population or not. The simplest normality test is to make a frequency distribution graph of existing scores. Testing normality depends on our ability to look at data plotting, (Usmadi 2020). In this study, the calculation of the initial test normality test was carried out using the Kolmogorov Smirnov method with a significance level of 0.05. It is known that the value of $L_{obs}$ in each group is less than the KS table value with a significance level α 0.05 based on the KS table obtained in the STEM group 0.084, the PjBL group 0.13 and the Expository Group 0.149 based on the KS table with a significance level of 0.05 (0.269). Thus, the data in each sample comes from a normally distributed population. Then the Data Normality Test of STEM Learning Model Data, PjBL and Conventional Learning after treatment in this study can be calculated in each group, based on the STEM, PjBL and expository learning models. using the Kolmogorov-Smirnov test with a significance level α 0.05. It is known that the D difference value in each group has a value smaller than the KS table value. Therefore, in each group the D difference value, so it can be said that at a significance level α 0.05, (KS table = 0.269) while the value of D STEM = 0, 0.084, D PjBL = 0.133 and D Expository = 0.104. Thus, it can be concluded that the post test is normally distributed.

***Homogeneity Test of Initial Ability of STEM Learning Model, PjBL and Conventional model (Lecture)***

Homogeneity test is carried out to determine whether the samples used come from a population with homogeneous variance or not. Homogeneity test with the aim of knowing how many variants of the population are the same or not by means of the t test or anova, of course this test is very important to do before comparing 2 or 3 groups or more so that the data does not have inhomogeneous differences, (Usmadi 2020). In this study, the homogeneity test was calculated using the Bartlett Test test with a significance level of 0.05. It is known that Che Squere $X^2_{obs}$ 1.097 $<X^2$ Che Squere with a significance level of 0.05; 2; (5.9914) So that $X^2_{obs} \notin$ DK and results in the test decision $H_0$ accepted Thus, it can be concluded that the variance of the research population is homogeneous (the same). While the data

homogeneity test for STEM, PjBL and Conventional Learning models uses the Levene test with a significance level of 0.05. It is known that the value of the three groups based on the calculation of the levene test with a significance level of α 0.05 is smaller so that $H_0$ is accepted can be seen in the results of the levene statistic = 1.4014 <α 0.05 (3.13814) That means, at a significance level of 0.05, the variance of the three groups based on the STEM PjBL learning model and lecture learning comes from a homogeneous population variance.

***Balance Test***

The balance test was conducted before the research sample groups were given treatment. This balance test was conducted to determine whether the samples to be used in the study had balanced initial ability of critical thinking skills or not. This balance test is then associated with the level of independence in the learning process can be divided into three levels, namely low, medium and high. (Susanti and Ritonga 2022). Thus, to calculate the *ANOVA* test (Analysis of Variance One Way Unequal Cells) with a significance level α 0.05 is used. It is known that the number of squares between groups in the three variances is 412,000 with db / free degree of 2, then the average number of squares / RJK is 206,000 and RJK error is 81,617 thus the calculated F( $F_{obs)}$ = 2.52 and $F_{tabel}$ =3.143, The critical area / DK in this balance test is { F I F> 3.03}. Therefore, $F_{obs}$ ∉DK. This means, at a significant level of 0.05 $H_0$ is accepted. Thus, it can be concluded that the samples to be used in the study come from a population that has the same or balanced initial ability of critical thinking skills.

***Effectiveness of STEM, PjBL and Lecture learning model development***

Based on the data on the effectiveness of the development of STEM learning models, PjBL and lecture learning can be seen in table 3.

Table 3. Data on the effectiveness of the development of STEM, PjBL learning models and Lecture learning

| Model | Teacher Activity | Group Work | Response Questionnaire | | |
|---|---|---|---|---|---|
| | | | Min | Max | Average |
| STEM | 82% | 83.33% | 70 | 83 | 76.00% |
| PjBL | 86% | 83.33% | 70 | 83 | 76.39% |
| P. Lecture | 66.7% | | 60 | 76 | 66.40% |

Source: Primary data

It can be seen in table 3 that the STEM model with an average of 82% teacher activity, 83.33% group work activity and student response questionnaire with a minimum score of 70, a maximum of 83, the average score is 76%, with these results it can be concluded that the development of the STEM learning model is very effective. These results can then be concluded. That the STEM/STEAM learning model or approach is able to provide learning effectiveness on students' critical thinking skills. (May 2023) In addition, the development of the PjBL learning model with an average teacher activity of 86% group work activity 83.33% and student response questionnaires with a minimum score of 70, a maximum of

83, the average score of 76.39% can be concluded that the development of the PjBL learning model is very effective. These results can then conclude that critical thinking skills are needed and very important and should be understood by students and to improve thinking skills and Self Efficacy of course need to apply the PjBL-STEM model or method. So it can be concluded that there is in the use of the PjBL - STEM model to improve students' critical thinking skills and self-efficacy. (Tirka 2021). The next result is the lecture group, with *66.7%* teacher activity and a response questionnaire with a minimum score of 60, maximum 70 with an average of 66.40%, it can be concluded that lecture learning is less effective. One of the studies proved the conventional lecture method and the animation-assisted lecture method on the installation of the brake system and then concluded that the animated video and lecture learning will give different results because in learning there needs to be a connection with field conditions so that students can see and practice and then follow, thus it can be concluded that the lecture method assisted by animation media can improve learning outcomes, (Beni Harsono et al 2009). From the results of this study then draw a red thread that cerama learning (convention) has not been able to improve the ability to think critically, because students have not been able to channel the learning process in a class that does not involve them based on the results that have been obtained.

***Post Test Results Data (Final Test) STEM Learning Model, PjBL (Project Based Learning) learning model and lectures***

Data on *Post Test* Results (Final Test) the development of a learning model is one of the achievements of a teacher in carrying out the planned process Thus the data on the results of the *post test* (Final Test) can be in table 4.

Table 4. Description of critical thinking *post test* data of learning model class STEM, PjBL and Control

| Group | N | Min. | Max. | $\bar{X}$ | SD |
|---|---|---|---|---|---|
| Experiment 1 | 24 | 65,7 | 82,9 | 77,02 | 4,9 |
| Experiment 2 | 24 | 68,6 | 82,9 | 76,19 | 4,2 |
| Control | 20 | 60 | 77,14 | 69,71 | 5,8 |

Source: Primary data

Based on table 4. After the treatment, there is a difference in the average value, it is known that the Experiment 1 class, the average value is 77.02, with a minimum value of 65.7 and a maximum of 82.9 and a standard deviation of 4.9. Likewise with the Experiment 2 class, the average value is 76.19, with a minimum value of 68.6 and a maximum of 82.9 and a standard deviation of 4.2. While the control class has an average value of 69.71 with a minimum value of 60 and a maximum of 77.14 and a standard deviation of 5.8 Thus the results of the *post test of* these three models provide different results. Can be seen in figure 2.

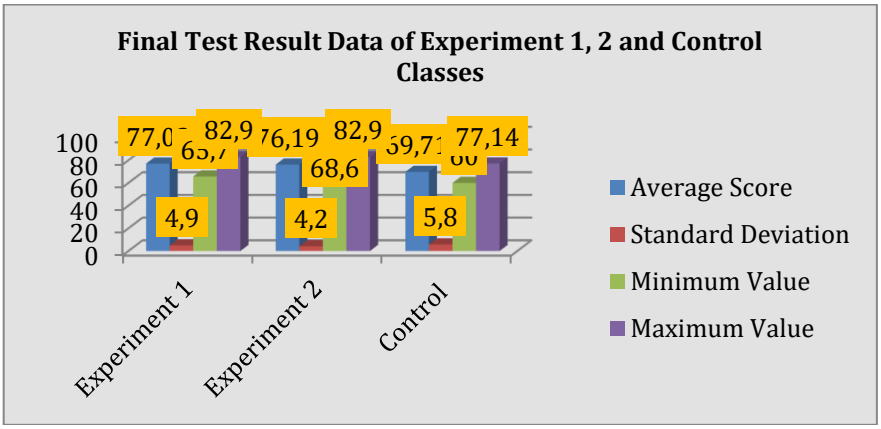


Figure 2. The results of the initial data description of the ability to think critically

**Research Hypothesis Testing Requirements**

***Hypothesis Test Results***

Based on the prerequisite analysis test that has been carried out, the data in the study can be tested hypothesis. Hypothesis testing is one of the answers that must be proven in other words, it is a temporary answer that is in the formulation of research problems, the problem formulation is also in the form of a question sentence. Why is it said to be a temporary answer, because the answer is based on relevant theory, there are no empirical facts obtained through data collection. So the hypothesis can also be stated as a theoretical answer to the formulation of research problems, belik an empirical answer, (Wijanto 2018) in (Majapahit 2023). Hypothesis testing is done to answer questions in research. before. The research hypothesis test was carried out with the One Way Unequal Cell Anova Test which can be seen in table 5.

Table 5. Summary of the calculation results of analysis of variance one unequal cell path

| Source of Variant | JK | db | RJK | F count | F table (α=0.05) | Test Decision |
|---|---|---|---|---|---|---|
| Between Groups | 679,08363 | 2 | 339,54181 | 13,8581 | 3,1400 | H0 rejected |
| Error | 1592,5850 | 65 | 24,501308 | | | |
| Total | 2272 | 67 | | | | |

Based on Table 8. It is known that one-way variance analysis of equal cells where there is the number of squares between groups (JKA) = 679.08363; the value of free degrees (db) = 2 and the number of squares in the group JKD = 1592.5850; while the average number of squares (RJK) with free degrees (db) 2 = 339.5418 while the average number of squares (RJK) with free degrees (db) 65 = 24.501308. While the value of $_{Fhitung}$ = 13.8581 and $F_{0,05;2;64}$ =3.14, so $F_A \in$ DK. The DK Anova one-way Unequal Cell for the learning model in this study is { F I F > 3.1400}. Thus, $H_0$ is rejected, which means there are differences in critical thinking skills using STEM, PjBL and expository learning models. Based on the results that have

been described, it is known that there is an interaction between the STEM learning model, PjBL and expository learning. In other words, Ho is rejected so that further *post-anova* tests are needed to answer the research hypothesis.

***Further Test of Multiple Comparisons (Scheffe Test)***

The further comparison test of multiple comparisons, the Schefee test was carried out to determine the most effective learning model among the three models tested to see how much students' critical thinking skills were. To know the further test of multiple comparisons has a goal where to find out whether there is a relationship between two variables or with independent and dependent variables. (Pinton Setya Mustafa 2023). Therefore, it can be seen that the summary of the results of the comparison test of means between rows is presented in table 6.

Table 6. Summary of Cell Averages and Marginal Rates

| n | F1 | Marginal |
|---|---|---|
| Model P. STEM | 77,02 | 72,02 |
| P. PjBL model | 76,19 | 76,19 |
| Expository | 69,71 | 69,71 |
| **Marginal Mean** | | **72,64** |

Based on Table 6. It is known that on a marginal average, the STEM learning model 72.02 with the PjBL learning model provides the same good critical thinking skills results as expository learning. And the PjBL learning model provides better results than the Expository learning model, the full results can be seen in table 7.

Table 7. Summary of Inter-Row Mean Comparison Test Results

| No. | Comparison | Fs (Fcount) | Ftable | Description | Test Decision |
|---|---|---|---|---|---|
| 1 | $\mu_1$ vs $\mu_2$ | 0,340118 | 6,276284 | $F_{obs} < F_{tabel}$ | $H_0$ accepted |
| 2 | $\mu_1$ vs $\mu_3$ | 23,78907 | 6,276284 | $F_{obs} > F_{tabel}$ | $H_0$ is rejected |
| 3 | $\mu_2$ vs $\mu_3$ | 18,67405 | 6,276284 | $F_{obs} > F_{tabel}$ | $H_0$ is rejected |

Based on Table 7, the following decisions can be made:

a) The first comparison was conducted to determine the effectiveness between STEM and PjBL learning models. In the first comparison, the value of F = 0.340118 was obtained so that F ϵ DK with DK = { F I F > F (2) $F_{0,05;2;64}$ }. The test decision on the first comparison $H_0$ is accepted which means that the second model of STEM learning model development gives an equally good effect on students' critical thinking skills.

b) The second comparison was conducted to determine the effectiveness between STEM and expository learning models. In the second comparison, it is known that FϵDK with the value of F = 23.78907 and DK = {FIF>F (2) $F_{0,05;2;64}$ }. Thus, $H_0$ is rejected. It means that the STEM learning model gives a different

effect from the lecture learning model on improving students' critical thinking skills.

c) The third comparison was conducted to determine the effectiveness between the PjBL learning model and expository learning. In the third comparison, it is known that F $\epsilon$ DK with the value of F = 18.67405 and DK = { F I F > F $(2)_{F0,05;2;64}$ }, so $_{H0}$ is rejected. It means that the PjBL learning model provides a different effect from the Expository learning model on improving students' critical thinking skills.

**Discussion**

The research was conducted to determine the effectiveness of the development of STEM and PjBL learning models to improve critical thinking skills on the subject of managing Indonesia's natural resources in class XI IPS SMA N 8 Kota Ternate.

***Effectiveness of STEM Learning Model Development on Critical Thinking Ability***

The results of the calculation of this research hypothesis test show that the three learning models used have different effects on students' thinking skills. Based on the calculations and research that has been done, it is known that the STEM and PjBL learning models are equally good.

Based on the research results, it is known that the STEM learning model is more effective than other learning models in improving students' critical thinking skills. This is due to the important role of STEM learning where STEM is a new pedagogy to respond to what students need in increasing their interest in the world of technology, science, and math (Perignat & Katz-Buonincontro, 2019 in (Lestari, Eraku, and Rusiyah 2021). In addition, the STEM approach also involves students in STEM metacognitive activities that have a classroom implementation that provides opportunities for students to understand the importance of integrating different disciplines and their applications (Anwari et al., 2015 in (Lestari, Eraku, and Rusiyah 2021). (Lestari, Eraku, and Rusiyah 2021).Thus STEM (*Science, Technology Engineering, and Mathematics*) (STEM) is able to provide students with creative abilities in linking the four fields of exact science so that students have deep and dynamic insights in solving related learning materials that have been given. (Lestari, Eraku, and Rusiyah 2021). For a teacher to be able to choose a learning model that can center on students, one of which is the STEM learning model. STEM-based teaching materials with EDP models on global warming material This study aims to determine the level of effectiveness and student responses after being taught using STEM-based teaching materials with the research model providing an increase in student learning outcomes before and after using STEM-EDP-based teaching materials, (Triwulandari et al. 2022)

***Effectiveness of PjBL Learning Model Development on Critical Thinking Ability***

The results of the calculation of the research hypothesis test show that each learning model gives a different effect on critical thinking skills. Based on the

calculations and research that has been done, it is known that students with the PjBL learning model are more effective. the importance of the world of education today that has experienced the development of the times, it is possible that an educator must be able to choose an interesting learning model and be able to make the ability to think critically present in students, the *project-based* learning model is very effective for learning in the classroom, because it fosters students' knowledge and skills through homework and practical work so that students can better understand the material that has been given, and make students better at thinking creatively and being able to solve a problem. (Muhammad Nurullah 2021). In addition, it can make students directly combine or link elements of knowledge and creativity (*soft skills*) in learning, namely knowledge and skills to plan an activity, problem solving, and communication of the results of activities or products, in addition to students mastering the content of a subject. Learners gain various learning experiences through the use and development of process skills and scientific attitudes. (Alrini Meisat Djaledje 2023)

***Effectiveness of Expository Learning (lecture)***

If the learning method is applied only alone and not applied with other approaches or ways there is a possibility that learning can be carried out, but it is not effective and not all learning material can be captured by a student. Sometimes there are teachers who do not understand learning methods so that when explaining the voice issued is very small and cannot be heard by all students and there are even teachers who when explaining the tempo is too fast and also makes students unable to understand what they are explaining. Therefore, a teacher must really understand learning methods and also other learning strategies well. discussion (Pratiwi 2019). Therefore, it is necessary to apply the approach with learning methods and other learning strategies. Learning methods do not consist of only one type but consist of several types. Kusnadi (2018), states that learning methods consist of: general methods and specific methods. General methods, such as lecture methods, question and answer methods, and discussion methods. (Pratiwi 2019). With the method used in this study, one of them is the lecture method based on the above quotation that the lecture method is not effective so that the results obtained in this study are in line with this statement.

***Effectiveness of Learning Model Development on STEM, PjBL and Lecture Learning on Critical Thinking Skills***

An educator needs to use a learning approach that can train students' creative thinking skills. One of the learning approaches that can be used to train creative thinking skills is based on *Science, Technology, Engineering, and Mathtematics* (STEM). (Arafah 2021). Digital teaching materials provide convenience and fluency in the learning process through active and independent learning. In addition, the benefits of teaching materials can help provide information related to the material, increase students to think or understand, and provide direct (concrete) experience to develop sustainably. (Prastyo, et all 2021). From the results and discussion of this study, there are limitations experienced when carrying out research, including time constraints in developing learning models because at

school, not only one subject is taught so that the predetermined time is finished, other subjects are ready to wait. Thus there needs to be careful planning so that it can run well.

## CONCLUSION

Based on the results of the above research, it can be concluded, using the development of STEM learning models, PjBL models, and conventional learning in accordance with these results, the development of STEM and PjBL learning models is very effective for improving students' critical thinking skills.

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