The Effect of STEM Integrated Project Based Learning Model on Students' Critical Thinking Ability in Geography Subjects

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Abstract: Critical thinking ability is a 21st-century skill that is still lacking well empowerment. Efforts that can be made to improve These skills are through student-centered learning. Model STEM integrated Project Based Learning encourages contextual learning through project activities. Indirectly, this builds thinking skills critical students in each syntax. This study aims to identify the effect of the model STEM integrated Project Based Learning on student's critical thinking skills in Geography subjects. This research uses a quasi-experimental research type by applying the post-test only control group design. The research subject is students of class X IPS 7 and X IPS 9 MAN Bondowoso. The instrument used is a test essay. Data analysis using independent samples-obtain test information p-level 0.00<0.05 with a mean post-test score of the experimental class 82, and control class 70. It is concluded that the STEM integrated Project Based Learning model has a significant effect on critical thinking skills.

Keywords: Project Based Learning model, STEM, Critical Thinking Skill

Education is an important component in the current 21st century because competition is getting tougher, requiring students to have a good expertise in various fields. In growing students' skills, learning is needed to guide students to activate their minds. Learning can be carried out by directing students to activate their own knowledge. For this reason, learning must be able to relate students' knowledge to real problems (Zulkarnain et al., 2016). Through this learning process students can increase their knowledge by studying the natural surroundings and developing beneficial skills in life.

A good learning model that fosters students' skills by associating learning materials with contextual problems is Project Based Learning (Gülbahar & Tinmaz, 2006). This learning model directs students to research collaboratively with groups and produce a product to solve challenges or problems (Suranti et al., 2017). In the process students are directed to make projects that are focused on establishing a product through assessment to solve problems.

The final result of Project Based Learning learning is in the form of group work in the form of products that focus on problems in Geography material. This is because the Geography material covers broad and complex discussions, so a learning process is needed to help students interpret the learning process by concretizing the learning material. One way to concretize learning material is by associating students' knowledge with the problems around them.

Honing students' ability to build new knowledge and problem solving skills requires integration with other scientific fields. This integration is based on the current educational focus that focuses on a problem where the answer is easy to know, there is only one solution, and the focus is on teaching students to get the correct answer. In contrast, real-world problems are unvivid and without a single correct answer (Diana et al., 2021). Learning needs to adapt to the current era by integrating STEM. STEM integration is learning in the fields of Science, Technology, Engineering and Mathematics aims to improve students' thinking skills (Liao, 2016). Therefore, the integration of STEM in the Project Based Learning model provides a contextual and practical learning process for students to solve problems.

STEM integration in the Project Based Learning Model in the learning process provides opportunities for students to interpret and understand the learning concept more fully (Afifah et al., 2019). In the exercise of the STEM integrated Project Based Learning model, students must build STEM concepts in science activities like designing technology that can simplify the process of product designing according to mathematical calculations (Sahin, 2015). Diana et al., (2021) argues that Project Based Learning combined with STEM can optimally improve students' abilities. Therefore, students are guided in developing knowledge that successfully solves problems by finding solutions to problems.

The Project Based Learning model that is integrated into STEM is different from the usual Project Based Learning model. The difference lies in the process of designing products made by students (Capraro et al., 2013). Integrating STEM into the Project Based Learning Model by including STEM components in the syntax. The steps of the STEM integrated Project Based Learning model are as follows (1) determine essential questions that aim to make students understand the focus of the project, determine the type of project and direct the investigation process, (2) design a project plan that includes selecting project types based on essential issues and determining activities in the investigation process, (3) arranging a project timeline so that students have expertise in time management, self-management and collaboration, (4) overseeing the course of the project by measuring progress, and overcoming obstacles and problems in preparing the project, (5) assessing project results by measuring and analyzing solutions based on problems (6) evaluating project results and reflection by providing suggestions and impressions of project results, while students redraw the project activities carried out (Hamidah et al., 2020).

The STEM integrated Project Based Learning model has several weaknesses, especially in technical matters, where students need a large and large amount of time and money to complete the project, and there may be students who are not involved in group work (Hafsah Adha Diana & Veni Saputri, 2021). The advantages of the model used have a considerable effect on student skills. Students are involved in finding real solutions to challenges and problems that are increasing motivation effectively (Asghar et al., 2012). Naturally, various aspects of STEM that are integrated into the Project Based Learning model encourage the imagination and sense of students' curiosity, thus increasing their enthusiasm for learning and scientific process skills (Capraro et al., 2016). Therefore, it can develop critical thinking skills while enhancing high-level skills.

The ability to solve a problem is part of the thinking process, especially critical thinking. The ability to think critically is a form of student skill to select, sort, process, and evaluate all information structures obtained to draw conclusions and make decisions (Sularmi et al., 2018). It is because critical thinking skills emphasize students to develop ideas or ideas as a basis for problem solving during the teaching and learning process (Diharjo et al., 2017).

There are twelve indicators of critical thinking skills, including (1) formulation of the main problem, (2) making questions and answering questions, (3) analysis of arguments, (4) considering relevant sources of information, (5) observing and considering the results of observations, (6) make deductions and consider them (7) make inductions and consider them, (8) evaluate and consider considerations, (9) present and assess the results of exposure, (10) identify assumptions, (11) decide an action, (12) communicate and interact with people (Ennis, 1996). Based on the twelve indicators presented, it can be concluded that the characteristics of a person is the ability to think critically, namely the ability to observe events in detail which is then analyzed based on accurate information that has been verified so that they can make conclusions based on these events with the right reasons.

The critical thinking indicators used are the conclusions of the twelve indicators that are summarized into five main actions, namely: (1) give a simple explanation; (2) build basic skills; (3) make conclusions; (4) provide a further explanation; and (5) setting strategies and techniques (Ennis, 2014). Overall, the five indicators used contain definitions of critical thinking skills, namely knowledge presented based on supporting evidence accompanied by a final conclusion from what description will later become the basis for taking action on a problem. Therefore, students' critical thinking skills can be seen based on the five indicators used.

Thinking skills can be grown with a learning process that can equip them to think logically, analytically and critically (Diansyah, 2018). In addition, a skill can help students to analyze existing problems (Akhmad et al., 2018). Compatibility with the material on the dynamics of the lithosphere and its impact on life requires students to be able to analyze environmental problems and provide the right solutions. Thus, learning Geography requires students' ability to think critically.

Based on the results of a literature study on previous research, it is known that the STEM integrated Project Based Learning model is still rarely carried out in Geography of class X high school, especially in the material on Lithosphere Dynamics and its impact on life. Research using the STEM integrated Project Based Learning model is applied more frequently to science subjects. Departing from this statement and supported by the advantages of the STEM integrated Project Based Learning model, the research was tested on high school Geography subjects. This study aims to analyze the effect of the STEM integrated Project Based Learning learning model on students' critical thinking skills in Geography.

METHOD

The method used in this study is a quasi-experimental research design by applying the post-test only control group design which was tested on students in class X7 and X9 at MAN Bondowoso as the experimental and control classes. The selection of experiment and control classes was executed using the purposive sampling technique by looking at the closeness of the values in the previous daily tests. From the two selected classes, then a lottery will be drawn to determine the treatment. The experimental class in this study was class X7 with an average daily test score of 82 was guided in the form of an integrated STEM Project Based Learning learning model, and class X9 with an average daily test score of 83 was a control class using a conventional model.

The instrument used is an essay test with five questions with a difficulty level of C4-C6 that is adapted to indicators of critical thinking skills using materials on lithosphere dynamics and their impact on life. The assessment of each test item was carried out by referring to the scoring rubric in Table 1.

Table 1. Critical Thinking Skills Assessment Rubric

Score	Description
6	All main points are specified and support the main idea All reasons and evidence are credible Supporting strong conclusions All sides of the discussion are clear and continuous
5	Points are stated clearly Many reasons and credible evidence Good conclusion support All sides of the discussion are mentioned, but not all of them are developed
4	All sides of the discussion are mentioned, but not all of them are developed Several reliable sources Evidence of sufficient support Including important things
3	Delivery is less and wordy Some sources or reasons are dubious Some support is still not enough Lack of mastery of paragraphs
2	Confused and main point not clear Unreliable sources Few conclusions support Paragraphs are not clear
1	Unable to explain the main point There is no reliable source Do not include reasons Unable to link

(Fiken & Ennis, 1996)

The instrument will be tested first for feasibility before being given to research subjects. The feasibility test includes: (1) testing the validity of the questions, using the moment product correlation formula aims to determine the validity of each question that has been made; (2) testing the reliability of the questions, using the Cronbach's Alpha formula to find out whether the questions are consistent even though they have been tested repeatedly.

Data were analyzed using Independent Samples-Test. The requirements are the data normality test and the homogeneity test. Hypothesis testing is based on the sig value. (2-tailed) that is, if the result is more than 0.05 then H0 is rejected which states there is no influence from the learning model. Whereas if it is less or equal to 0.05 then H0 is accepted, which states that the STEM integrated Project Based Learning model affects students' critical thinking skills in Geography subjects.

RESULTS AND DISCUSSION

Results

Based on Table 2, the value of the sig experimental class is 0.205 > 0.05 and sig. 0.456 > 0.05. These results are interpreted as if the data were normally distributed. Data that is normally distributed indicates that the instrument used to measure critical thinking skills has a precise objective assessment and avoids judgments that lean towards only one category. Homogeneity test results show sig. 0.069 > 0.05, so the data is homogeneous. The homogeneity test aims to determine whether two or more samples from different populations have the same distribution of variance or characteristics. This indicates if the requirements for testing the hypothesis have been fulfilled. Based on the hypothesis test, it is known that the sig. (2-tailed) is 0.00 < 0.05. These results mean that there is an influence of the STEM integrated Project Based Learning model on students' critical thinking skills in Geography.

The correctness of testing the hypothesis is proven by looking at the mean post-test value in Table 3. Table 3 shows the average post-test for the experimental class is 82, while in the control class, it is 70. This value is evidence for the correctness of hypothesis testing.

Based on the analysis of the post-test score calculation results, it can be seen in the distribution of scores on each indicator and the percentage of critical thinking skills in the experimental and control class as well as in Table 4. Table 4 shows that students who use the STEM-integrated Project Based Learning model and students who use the system of conventional learning on students' critical thinking skills are very different.

Table 2. Post-test Score Analysis Data

Class	Normality Test	Homogeneity Test	Hypothesis sample t-test
Experimental	.205	.069	.000
Control	.456		

Table 3. Mean Score

Class	N	Mean
Experimental Class	30	82.2000
Control Class	30	70.3667

Table 4. Average Critical Thinking Ability Indicator Score

Indicators	Experimental Class	Category	Control Class	Category
	Mean		Mean	
Giving a simple explanation	5,6	Very Critical	4,5	Critical
Building basic skills	4,1	Critical	3,6	Sufficient
Establishing inferences	4,2	Critical	3,3	Sufficient
Providing further explanation	4,7	Critical	4,1	Critical
Setting strategies and techniques	5	Very Critical	2,9	Sufficient

Discussion

In addition to improving student learning outcomes, STEM integration into the Project Based Learning model also has advantages in fostering students' critical thinking skills (Fitriyah et al., 2021). The integration of STEM into the model used is as follows: (1) science, by applying vegetative and mechanical land conservation materials in Biology and Mathematics, namely the anatomical structure of plants and slope angles. The science process is used in syntax 1 and 5. (2) Technology, namely the learning process by utilizing Google Earth technology to contextualize eroded land problems in syntax 1. (3) Engineering, namely the design of an erosion test tool using vegetative and mechanical methods in syntax 2. (4) Mathematics in the process of designing an erosion test tool that must be set in measurement to the problem given according to the LKS in syntax 2 and 5.

Learning activities refer to the steps of the Project Based Learning model by integrating STEM aspects. The first stage is to determine the essential questions. At this stage, students carried out science practice by providing basic questions in the context of actual problems with the help of technology. Introducing issues to students must start from real situations in the form of natural phenomena that are relevant to the material (Priatna et al., 2020). Introduction to the problem is by providing a picture of the erosion events that occurred in Bondowoso, precisely in Sempol Village, Ijen District, which is integrated with Google Earth shown in Figure 1 below.

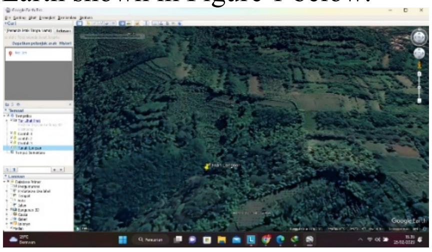

Figure 1. Technology Utilization

Figure 2. Land Form Differences

Departing from these problems can give assignments to students in knowing the effect of soil conservation. Furthermore, students were divided into four groups by completing two projects for each, the first project to make an erosion test tool on flat land. In project 1, students made tools with three types of treatment using vegetation cover, mulch and without cover. For project 2, students made an erosion test tool on sloping land by changing the shape of the land with terracing and without changing it. Problems that later become fundamental questions can improve students' critical thinking skills because they require students to provide simple explanations of questions and build fundamental skills on given problems (Hikmah et al., 2016). In addition, essential questions allow students to focus on the project to be executed so that students' analytical ability can focus on these problems that can directly improve critical thinking skills (Dischino et al., 2011).

The second stage is to design project plans in collaboration between students and teachers to build STEM-integrated projects. Planning at this stage contains rules for (engineering) designing projects 1 and 2 on flat and sloping land conditions, which must be adjusted to the mathematical aspects. At this stage, students are directed to discuss with groups and gather information, and they are given the opportunity to ask questions about the project being carried out. The ability to think critically can involve the ability to organize strategies and techniques in planning, starting with selecting the tools and materials used to obtain the appropriate results (Novitri Antik, 2017; Priatna et al., 2020).

The third stage is compiling a project timeline. Teachers and students agree on a timeline of completing the project in the form of a production schedule. At this stage, the teacher gives an overview of completing the project. The fourth stage is overseeing the running of the project. Students are given space to design the process of making a product, which can be consulted with the teacher, and if it is appropriate, it can be continued at the work step stage (Meita et al., 2018). At this stage, the teacher pays attention to every process carried out by students for the success of their projects (Izzati, 2014).

The fifth stage is assessing the results of the project. At this stage, students apply the discipline of Mathematics in measuring the rate of erosion and Science in analyzing the effect of cover (buffering) and landforms on the rate of erosion in Table 5 below.

Table 5. Student Analysis Results

Project 1			
Buffer Type	Water Amount	Erosion Amount	Analysis
Vegetation Soil Mulching Vegetation	440 ml 440 ml 440 ml	Turbidity 2 cm Turbidity 1,5 cm Turbidity 0,5 cm	Plants help reduce the rate of erosion because plant roots can restrain the surface runoff rate and bind water droplets into the soil pores, while the use of mulch can reduce the rate of erosion because it reduces the kinetic energy when it rains.
Project 2			
Terracing Type	Water Amount	Erosion Amount	Analysis
Without Terracing Vegetation Terracing	1 liter 1 liter	Turbid Precipitate 10 cm Turbid Precipitate 2 cm	Terracing reduces the rate of erosion because the flow rate decreases as a result of being restrained by the terracing form of food

Based on the results of the student analysis will also be presented in front of the class. A crucial point in the assessment is the result of the student's analysis of the effects of the causes of erosion based on the findings of the trial tool that has been designed. The results of student analysis lead to a logical and rational conclusion to find a solution to the initial problem (Davidi et al., 2021). In addition, at this stage students also communicate by providing further explanations to understand the problem. Students are better at understanding learning material and are able to make inferences (Noviyanti, 2011).

The last stage is evaluating the project results and reflecting on it. This stage is in the form of re-examining and criticizing activities. If these two activities are related to thinking ability, then check again to measure how successful the design is on the problems given while criticizing is according to the critical thinking process (Gunawan & Paluti, 2017). Evaluating is a vital part of critical thinking skills because students can interpret the activities that have been carried out (Fisher, 2009; Legant, 2010).

This explanation shows that the STEM-integrated Project Based Learning model can improve critical thinking skills. The problems of questions that require students to plan, design and project results by integrating the STEM field of knowledge allow students to escalate critical thinking skills (Diana & Saputri, 2021). Students are invited to carry out a more meaningful learning process through research activity, so that students can play an active role in learning (Ismayani, 2016). Therefore, students understand the problem through an investigative process related to project assignments which begins by finding accurate sources, designing and collaborating with group members and even teachers in other fields.

In each Project Based Learning syntax, especially those integrated with STEM, syntaxes 1, 2, and 5 are important in building critical thinking skills. In the activity of cultivating critical thinking skills, students are not only passive by listening to the teacher but can also play an active role in it. A learning system that actively involves students in applying knowledge is a sign of students' critical thinking skills (Firdaus et al., 2015). The application of the STEM-integrated Project Based Learning Model fosters students' critical thinking skills because each syntax requires collaboration with group members, communication, and being able to solve problems (Fitriyah et al., 2021).

There are findings that are almost the same as this study, the findings of Fitriyah (2018) stating that if the Project Based Learning model is integrated with STEM it can become a learning innovation. In line with Arif's findings (2020), said that the Project Based Learning model is incorporated with STEM to train collaborative work, solve problems, design investigations and make reflection activities. These findings strengthen the results of this experiment. In addition, this research success is also evidence of the superiority of the STEM-integrated Project Based Learning model which motivates students because it fosters a caring attitude and critical thinking.

In this research on the STEM-integrated Project Based Learning model, several weaknesses were found, especially in technical matters. In project work, students need a relatively large amount of money to buy the tools and materials used to complete the project, and some students were not involved in group work.

CONCLUSIONS

Based on the research results, it can be seen that the STEM integrated Project Based Learning model has a significant effect on critical thinking skills with a sig. 0.00 < 0.05. This is because, with the integrated STEM Project Based Learning model, students can build the skills needed in the 21st century such as working together, making decisions, solving problems, being able to communicate and self-management which gives students the ability to think critically.

Related to the results and findings as well as the limitations found in the research, it is suggested for further researchers (1) Choose an economical project for students to reduce costs (2) Divide student groups evenly based on ability so that there are students who are able to coordinate work projects.

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