
The Effect of STEM on Class X Students' Learning Achievement and Critical Thinking Skills on Environmental Pollution Material

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Abstract. The success of learning process can be seen from students' achievements and critical thinking skills. One approach that can be used to improve learning achievement and CTS is STEM. Many researchers have conducted research on STEM, but have not been specific about the aspects that play a role on it. This research aims to determine the effect of STEM from the facility aspect, teacher aspect and environmental aspect on learning achievement and CTS. This survey research used purposive sampling involving 152 students. The research instrument consists of a questionnaire to see students' perceptions of STEM from three aspects and a test instrument to determine students' learning achievement and CTS. Data analysis was carried out using partial least square. The research results show that (1) the facility aspect has the greatest influence on learning achievement; (2) environmental aspects have the greatest influence on CTS; (3) the three aspects of STEM learning have a big influence on learning achievement and CTS; and (4) learning achievement greatly influences CTS. These results show that STEM is very feasible to be implemented in the classroom to improve learning achievement and CTS.

Keywords: Critical Thinking Skills, Learning Achievement, STEM

Introduction

Education is one way to produce superior and quality human resources to achieve national development goals. In educational activities there is a teaching and learning process to obtain information, skills, values and attitudes with the aim of forming individuals who are able to think systematically, rationally and critically. The success of learning process can be seen from students' achievements and CTS. CTS is a thinking skill that is an important indicator of the quality of student learning (Alsaleh, 2020). According to American Association of Colleges of Nursing (2008) CTS are all or part of the processes of questioning, analyzing, synthesizing, interpreting, inferring, inductive and deductive reasoning, intuition, application, and also creativity. Saavedra & Opfer (2012) stated that CTS should be empowered through the learning process in schools, especially science learning because CTS are 21st century thinking skills that students must have. CTS have been included in school learning since implementing the 2013 national curriculum in Indonesia (Sari, et al., 2021). CTS enable individuals to take a stand on scientific issues, logically rationalize the issues being discussed, to detect errors in arguments, or postpone

decision making when there is insufficient evidence to establish and support a conclusion (Tenreiro-Vieira, 2000). In addition, CTS are very important to be empowered because they can influence students' cognitive learning outcomes (Cano & Martinez, 1991) and are an important factor in achieving learning achievement. According to Djamarah (2017) learning achievement is the measurement result of an assessment expressed in the form of pictures, letters or sentences that describe the results that students have achieved within a certain period of time. The results of research conducted by Ismail (2011) stated that there was a positive relationship between students' cognitive abilities and their critical thinking abilities. A similar thing was also expressed by Palluvi (2010) who stated that cognitive learning outcomes and CTS cannot be separated because both depend on students' thinking abilities to handle a problem. Thus, there is a strong relationship between learning achievement and CTS which means students with good cognitive abilities will also have good CTS.

Based on observations made at one of MAN in Pekanbaru City, several problems were found in biology learning, namely; 1) the learning process is still in the form of remembering and understanding so that the focus of learning is just memorizing the material; 2) the STEM approach has not been fully implemented in the learning process; 3) the learning process has not trained CTS so that students' critical thinking abilities are low and; 4) the average student achievement in Biology is still low. Therefore, it is necessary to implement a learning approach that can train students so that their learning achievement and CTS can increase. To improve learning achievement and CTS, one way that can be done is to use a STEM approach. Anggraini & Huzaifah (2017) said that the STEM approach try to connects and integrates several STEM subjects as an effort to make problem-based learning in daily life and train students to apply the information they have learned at school with phenomena that exist in the real world. STEM is called interdisciplinary because it is based on the integration of various scientific disciplines into one new body of knowledge (Lantz, 2009). In learning, STEM includes the 4C abilities of the 21st century, namely critical thinking, creativity, communication and collaboration. STEM learning is very suitable for use in Biology learning because Biology learning is not only related to facts and concepts, but on the other hand is also related to the process of discovering, especially in environmental pollution material because in this material there are scientific disciplines to look at the causes of environmental pollution, the technological discipline to create technology that can reduce the pollution, the engineering discipline to find the solutions and the mathematical discipline to calculate the costs incurred to solve the problems.

There is a lot of research that proves that STEM learning can improve learning achievement and CTS, such as research conducted by Sarican & Akgunduz (2018) which found that the use of the STEM approach can help students gain knowledge by discovering and conducting experiments to prove hypotheses, which have been created so as to improve student academic achievement. The research results of Ritonga & Zulkarnaini (2021) also show that the implementation of STEM in learning can improve CTS, as well as Yaki (2022) who states that the STEM approach is effective in improving students' CTS. This STEM learning model can improve high-level thinking skills because it can facilitate students to solve problems, think critically, creatively, and scientifically (Baharin, et al., 2018). A similar thing was also conveyed by Izzani (2019) who stated that student learning outcomes increased with the use of the STEM learning model, this was shown by the learning outcomes of students with this model being higher compared to students who did not use it. Based on several previous studies, there is no detailed research regarding the influence of certain aspects of STEM learning such as facility aspects, teacher aspects and environmental aspects on learning achievement and CTS. Apart from that, there is also no research regarding which aspects have the most influence on learning achievement and

CTS as well as the influence between learning achievement and CTS. Therefore, by using the PLS approach, this research aims to answer the research questions as stated above.

Methods

This research is quantitative research with a survey method. This research was conducted to determine the effect of STEM learning from the facility aspect, teacher aspect and environmental aspect on students' learning achievement and critical thinking skills. The population in this study were all students of class X at one of MAN in Pekanbaru City, totaling 7 classes. The sampling technique used was purposive sampling with the consideration that students had carried out learning material on environmental pollution by applying STEM learning. The sample for this research was classes X.1, X.2, X.3, X.4 and X.5 with a total sample of 152 students. The research instrument for STEM learning is a questionnaire. This questionnaire is used as a tool to measure students' perceptions and opinions regarding the STEM learning they have participated in through three aspects, namely the facility aspect with five question items, the teacher aspect with six questions and the environmental aspect with eight questions. Meanwhile, for learning achievement and CTS, cognitive tests are used in the form of essay questions on environmental pollution material.

Analysis of the influence of STEM learning on students' learning achievement and CTS was evaluated using the structural equation modeling-partial least square (SEM-PLS) approach with SmartPLS v3.2.9 software. Data were analyzed using descriptive analysis techniques and path analysis. Descriptive analysis was carried out to obtain information regarding students' perceptions and opinions regarding STEM learning and the results of learning achievement as well as CTS. A path analysis was carried out to see the good or bad influence between STEM learning and learning achievement and CTS. This research consists of two types of variables, namely independent variables and dependent variables. The independent variable is STEM learning which is measured using three aspects, namely the facility aspect, teacher aspect and environmental aspect, while the dependent variable is learning achievement and CTS. The interaction of variables is shown in Figure 1 through a specification model to see the relationship between variables and the relationship between variables and their indicators.

Evaluation of the PLS model is carried out in two ways, namely assessing the outer model and inner model. Evaluation of the outer model involves validity testing and reliability testing. Validity tests include convergent validity and discriminant validity. Convergent validity is obtained from the outer loading value and average value extracted (AVE). Discriminant validity is obtained from the Fornell Larcker value. The reliability test is obtained from the cronbach alpha and composite reliability values. Next, evaluation of the inner model is obtained from the coloniality test, hypothesis test, R^2 value, effect size (F^2), and model fit to determine the suitability of the model and data. The evaluation criteria for the PLS model are shown in Table 1.

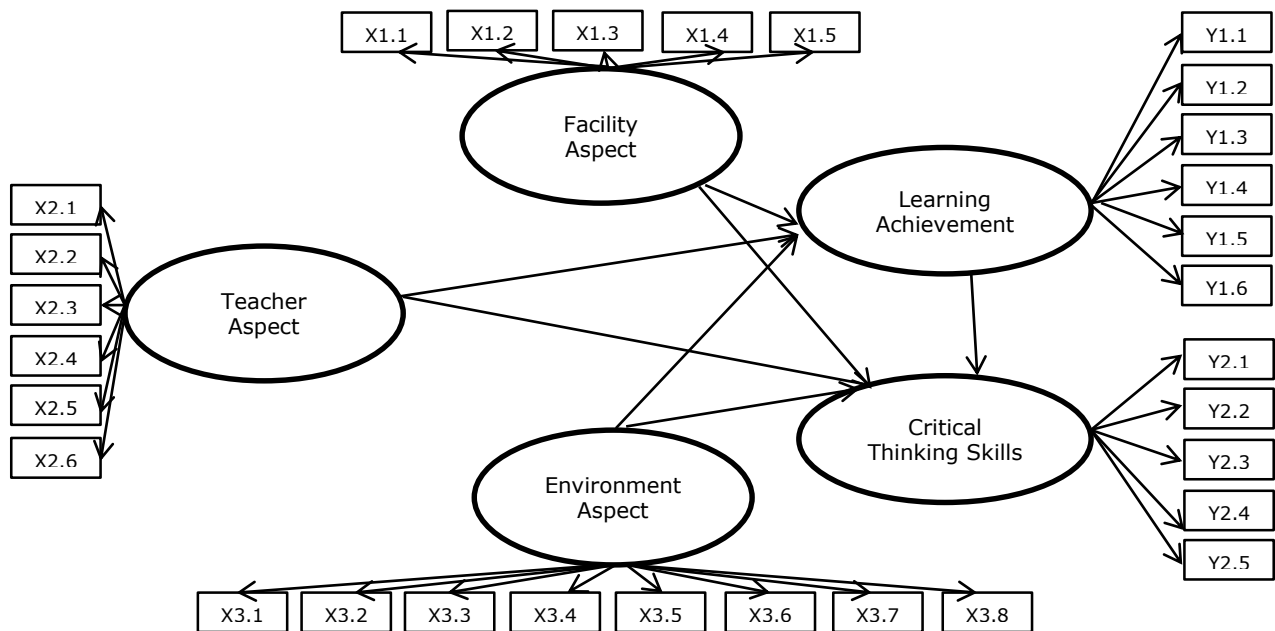


Figure 1. Spesifications model

Table 1. Summary of outer model and inner model evaluation

Criteria		Rule of Thumb
Outer Loading	> 0.70	
AVE	> 0.50	
Fornell Larcker	Root AVE > correlation between latent constructs	
Composite Reliability	> 0.60	
Cronbach Alpha	> 0.60	
VIF	< 5	
R ²	0.66 (strong), 0.33 (moderate), 0.19 (weak)	
F ²	0.35 (high), 0.15 (moderate), 0.02 (low)	
SRMR	< 0.08	

Results and Discussion

The results of the PLS analysis were carried out using two approaches, namely the outer model and the inner model.

Outer Model Evaluation Results

Analysis at this stage is carried out to determine the results of the validity and reliability tests. The results of estimating model parameters are shown in the following figure.

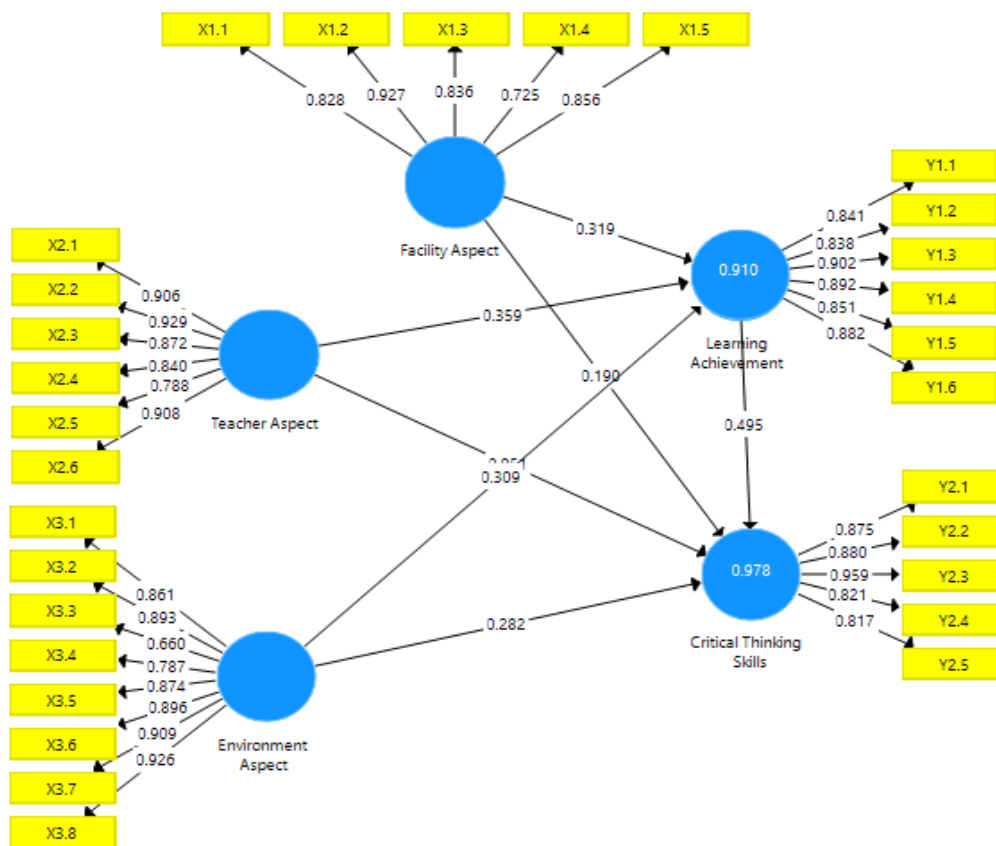


Figure 2. Estimations of parameter models

The convergent validity value is obtained from the outer loading value and the AVE value. The outer loading value in the model must be greater than 0.70 and the AVE value must be greater than 0.50. The evaluation results in Table 2 show that almost all items have a large outer loading value of 0.70, except for the environmental aspect of the third question item with an outer loading value of 0.660, which states that the question item is invalid. These invalid question items can be modified, replaced with new questions or removed with the note that deleting or removing these indicators from the model can increase the composite reliability value and the average variance extracted (AVE) value. The highest outer loading value is found in the third item critical thinking skills with a value of 0.959. For the AVE value, all constructs are above 0.50, which means that on average the constructs are able to explain more than half (50%) of the variance of each indicator. The highest AVE value is in the teacher aspect and the lowest AVE value is in the facilities aspect. In the reliability test, based on the cronbach alpha and composite reliability values, all question items on all indicators were declared reliable with cronbach alpha and composite reliability values > 0.60.

Table 2. Evaluation result

Variables	Indicators	Convergent Validity		Reliability	
		Outer Loading	AVE	Cronbach Alpha	Composite Reliability
Facility Aspect	X1.1	0.828	0.701	0.892	0.921
	X1.2	0.927			
	X1.3	0.836			
	X1.4	0.725			
	X1.5	0.856			
Teacher Aspect	X2.1	0.906	0.766	0.938	0.951
	X2.2	0.929			
	X2.3	0.872			
	X2.4	0.840			
	X2.5	0.788			
	X2.6	0.908			
Environment Aspect	X3.1	0.861	0.731	0.946	0.956
	X3.2	0.893			
	X3.3	0.660			
	X3.4	0.787			
	X3.5	0.874			
	X3.6	0.896			
	X3.7	0.909			
	X3.8	0.926			
Learning Achievement	Y1.1	0.841	0.760	0.920	0.940
	Y1.2	0.836			
	Y1.3	0.902			
	Y1.4	0.892			
	Y1.5	0.851			
	Y1.6	0.882			
Critical Thinking Skills	Y2.1	0.875	0.753	0.934	0.948
	Y2.2	0.880			
	Y2.3	0.959			
	Y2.4	0.821			
	Y2.5	0.817			

In SmartPLS v3.2.9, the comparison between the square root value of AVE and the correlation value between constructs can be seen from the fornell larcker criterion value. The square root value of AVE is displayed diagonally and the value below it is the correlation value between constructs (Table 3). So, if the square root value of AVE is higher than the correlation value, it can be concluded that the model is valid because it meets discriminant validity. However, from Table 3 it can be seen that all correlation values between latent constructs are greater than the square root value of AVE so that discriminant validity has not been met. Next, testing of the influence between variables will be carried out, known as inner model evaluation.

Table 3. Fornell larcker's criterion for discriminant validity

Variable	Facility Aspect	Teacher Aspect	Environment Aspect	Learning Achievement	Critical Thinking Skills
Facility Aspect	0.837				
Teacher Aspect	0.888	0.875			
Environment Aspect	0.878	0.939	0.855		
Learning Achievement	0.933	0.946	0.955	0.872	
Critical Thinking Skills	0.909	0.932	0.926	0.976	0.868

Inner Model Evaluation Results

The inner model evaluation aims to see the significance of all path estimates. In addition, this model is measured to describe the correlation between construct variables, so that the strength in predicting the model is known. The inner model can be seen from the coloniality test, hypothesis testing by looking at the path coefficient, R^2 value, F^2 and model fit.

The coloniality or multicollinearity test uses the variance inflation factor (VIF) to evaluate the level of correlation between independent variables in the regression model. VIF measures how well an independent variable can be predicted by other variables in the model. In SmartPLS, the VIF value of the independent variable in this study was found to be above 5. A VIF value above 5 is considered an indication of significant multicollinearity. A VIF value exceeding 5 indicates that the independent variable is closely related to other variables in the model so it needs to be identified further.

Table 4. Path coefficient values from the bootstrapping method

Connection	Original Sample	T Statistics	P Values	Interpretation
Facility Aspect -> Critical Thinking	0.190	4.543	0.000	Positive and significant
Facility Aspect -> Learning Achievement	0.319	5.631	0.000	Positive and significant
Teacher Aspect -> Critical Thinking	0.051	1.112	0.267	Positive and not significant
Teacher Aspect -> Learning Achievement	0.359	4.858	0.000	Positive and significant
Environment Aspect -> Critical Thinking	0.282	6.329	0.000	Positive and significant
Environment Aspect -> Learning Achievement	0.309	3.574	0.000	Positive and significant
Learning Achievement -> Critical Thinking	0.495	12.679	0.000	Positive and significant

The path coefficient is a value that aims to show the direction of the relationship between variables, whether the direction of a hypothesis is positive or negative. The results of the bootstrapping method on the path coefficients (Table 4) show that all relationships are positive when viewed from the original sample values with a value range between 0 to 1. The t statistical value must be greater than 1.96 because the alpha value used is 5%. The p value must be below 0.05 to be significant. From Table 4, it can be seen that only one value is below 1.96 and is greater than 0.05, namely the relationship between teacher aspects of critical thinking so that the influence between the two variables is not significant.

Table 5. R^2 value and assessment of the PLS algorithm results

Variable	R^2	Description
Learning achievement	0.910	Strong
Critical Thinking Skills	0.978	Strong

The value of the coefficient of determination R^2 indicates the magnitude of the combination of independent variables which together influence the value of the dependent variable. The higher the value, the higher the model prediction accuracy value obtained. Based on the R^2 value table, it can be seen that 91% (strong) of learning achievement is influenced by STEM learning from three aspects, namely the facility aspect, teacher aspect and environmental aspect, while critical thinking skills are influenced by the three aspects at 97.8% (strong). The remainder is influenced by other variables that are outside this research model.

Table 6. Effect size (F^2)

Connection	Critical Thinking	Learning Achievement
Facility Aspect	0.265 (Moderate)	0.221 (Moderate)
Teacher Aspect	0.010 (Ignored)	0.144 (Low)
Environment Aspect	0.358 (High)	0.116 (Low)
Learning Achievement	1.010 (High)	-

The results of the effect size (F^2) in Table 6 shows that all aspects of facilities, teachers and environment influence critical thinking skills and learning achievement. Likewise, learning achievement influences critical thinking skills. The relationship between learning achievement and critical thinking has the highest value, followed by the relationship between environmental aspects and critical thinking. The moderating effect is shown by the relationship between the facility aspect and critical thinking and the facility aspect with learning achievement. The low effect is shown by the relationship between teacher aspects and learning achievement and environmental aspects with learning achievement. Meanwhile, the relationship between teacher aspects and CTS is ignored or considered to have no effect because the value is below 0.02.

Model fit is used to see whether the model and data are appropriate or not to test the influence of variables. The requirement for a fit model is that the SRMR (standardized root mean square residual) value must be < 0.10 . The model fit value in this research is 0.078, which means the model and data are suitable for use to test the influence of variables.

The Influence of Indicators on Learning Achievement and Critical Thinking Skills

Validity measurements are carried out to see how well an instrument developed measures research. The higher the value of the instrument, the better it is at representing the research question. Reliability tests are carried out to prove the accuracy, consistency and accuracy of the instrument in measuring the construct. From the data from the validity and reliability tests, almost all indicators on learning achievement and CTS are able to reflect the construct variables and are in accordance with the predetermined criteria. There is only one indicator on the environmental aspect that is invalid, namely the third question item and modifications were made to this indicator.

The Influence of Facility Aspects, Teacher Aspects and Environmental Aspects on STEM Learning

In terms of learning achievement, the most influential aspect is the facility aspect, followed by the teacher aspect and finally the environmental aspect. Kartono (1985) states that whether or not the learning equipment is complete, whether owned by the student or the school, can provide certain results on student learning achievement. Lack of learning equipment can have negative consequences, such as students not being able to study well, making it difficult to expect them to achieve high levels of achievement. Surya (2004) also expressed the same thing, who stated that apart from learning resources, learning equipment must also be provided in full to support the learning process so that it runs well.

In research conducted by Putri (2019), Astuti (2019) and Permana, et al. (2018) found that there is an influence of learning facilities on student learning outcomes.

In CTS, the most influential aspect is the environmental aspect, then the facility aspect and finally the teacher aspect. Students' CTS are influenced by internal and external factors. One external factor that can influence students' CTS is learning environment. Students' experiences while interacting with their environment support the potential that exists within the student so it cannot be denied that the external environment such as the school environment also influences students' critical thinking abilities. This is in line with research conducted by Wahid, et al. (2020) and Hermawan, et al. (2020) who obtained the results that the school environment has a significant effect on learning achievement. According to Shohih (2015) supportive learning environmental conditions such as the availability of physical learning facilities, a comfortable place to study, a calm atmosphere, harmonious relationships with the social environment can provide support for students to learn so that their learning outcomes can improve. Likewise, if the learning environment is less supportive, it will reduce students' enthusiasm for learning so that their learning outcomes will decrease.

The aspect with the least influence is the teacher aspect, where this aspect has a low influence on learning achievement and no influence on CTS. This is contrary to existing theory where teachers play a role in planning learning with learning methods and strategies that are interactive, inspiring, fun, challenging so as to motivate students to be able to participate actively in the learning process. Thibaut, et al. (2018) state that teachers' attitudes are related to their teaching practices. Apart from that, Enciso, et al. (2017) stated that teachers play an important role in helping students develop their CTS. According to Morrison (2020), teachers are tasked with providing challenges to students and providing responsive guidance and suggestions, responding directly to students' interests while maintaining high standards and expectations, because teacher concern in an environment with high expectations is very important for student success. Giving assignments such as questions related to contextual analysis or problem solving by teachers can open up opportunities for students to develop their critical and creative thinking skills so that information obtained from student learning outcomes, experimental or practicum results can be remembered by students longer so that learning outcomes students will improve from before. Besides that, encouragement given by teachers can increase students' enthusiasm for learning, thereby increasing their enthusiasm and curiosity. This is in accordance with the theory put forward by Baret, et al. (2011) that learning with problem designs that are stimulated to students in different structures such as scenarios, cases, challenges, dilemmas, summaries, reports, random phenomena or other inducements, can encourage students to learn better.

The Effect of STEM Learning on Learning Achievement and Critical Thinking Skills

Based on R square value, it appears that all aspects of STEM learning, namely facility aspects, teacher aspects and environmental aspects have a big influence on learning achievement and CTS. The overall influence of aspects on learning achievement is 91% and on CTS is 97.8%. These two influences are included in the strong category. These results are in accordance with research by Khoiriyah, et al. (2018) which revealed that STEM learning reaches a confidence level of up to 95% and really helps students to improve their CTS. The same thing was also found by Marshall & Harron (2018) who stated that integrating STEM could have a positive impact on students' interests, especially in increasing CTS. Likewise, the results of research by Retnowati, et al. (2020) which states that the STEM approach can improve CTS with an increase in the average score of the experimental class. This is according to Murnawianto, et al. (2017) can occur because the application of STEM has comprehensive characteristics (problem solving and critical analysis) so that it provides great opportunities for students to practice their CTS. Apart

from that, in its implementation, STEM learning is more focused on active student participation so that it can encourage students to think critically. According to Roehrig, et al. (2021) the strength of this multidisciplinary STEM approach is its explicit learning. Stohlmann, et al. (2012) stated that STEM learning is able to improve students' high-level thinking skills and technological literacy, train problem-solving abilities, and make students great pioneers and creators. Likewise, understanding STEM according to Hacıoglu & Gulhan (2021) can increase students' critical thinking and perception of STEM positively and have implications for their career awareness.

Not only critical thinking, STEM also has a big influence on student learning achievement. Various studies have proven that the STEM approach has a positive influence on student learning achievement (Austin, et al., 2010; Hurley, 2010; Hernandez, et al., 2013; Jayarajah, et al., 2014; Yildirim, 2016; Sarac, 2018, Wahono, et al., 2022) and it has high potential in facilitating the learning process to achieve effective outcomes (Mustafa, et al., 2016; Martín-Páez, et al., 2019). This is because in the STEM approach students do not just memorize concepts, but rather how students understand these science concepts and their relationship to daily life so that according to Davidi, et al. (2021) can improve the ability to solve problems, make decisions, make assumptions, carry out investigations and evaluations. In addition, STEM topics and learning centered on real-world problems can spur student enthusiasm and motivation so that learning outcomes improve. According to Fadlina, et al. (2021) the STEM approach makes it easier for students to find new ideas well, be skilled in using tools and materials, easy to handle learning problems, easy to understand the material and makes students more active and motivated to learn. Furthermore, according to Sarican & Akgunduz (2018) academic achievement can increase through integrated STEM learning and in accordance with a constructivist approach but has a limited impact on academic achievement.

The Influence of Learning Achievement on Critical Thinking Skills

From the research data, it appears that there is a strong influence between learning achievement and CTS. Fitriani (2020) stated that student learning achievement can increase as students' CTS develop. Critical thinking includes active processes of analysis, evaluation and synthesis in processing information. Students can develop learning achievements through their cognitive abilities more effectively if they train themselves to think critically. The same results were also presented by Akpur (2020) that there is a positive correlation between critical thinking, reflective thinking and creative thinking skills on students' academic achievement. Handari & Sugeng (2010) state that the critical thinking process encourages students not only to receive information, but also invites them to reflect, relate it to previous knowledge, and apply it in various different situations. Thus, learning achievement and CTS have a relationship that complements and strengthens each other.

Taghva, et al. (2014) examined the relationship between CTS and student learning achievement. The results of his research revealed that there is a significant relationship between critical thinking and student learning achievement. These results are in line with the theory put forward by Marzano, et al. (1989) who explains that CTS are needed in learning activities because developing CTS in learning activities will make a positive contribution to learning achievement. Caroselli (2009) also stated that students' critical and creative thinking habits will have a potential effect on student learning outcomes at school, where the habit of solving problems critically and creatively will accustom students to solving problems accurately and quickly. Caroselli (2009) also added that critical thinking has an effect on a student's learning outcomes, where skills and accuracy, such as in solving problems, make students accustomed to arguing using various points of view according to the context of the problem. In line with this, Marzano in Slavin (2009) states that one of the goals of school is to improve students' ability to think critically, make

rational decisions about what to do and what to believe. Thus, CTS are important for students in improving their learning outcomes.

Conclusion

Based on the findings in the research results, it can be concluded that (1) the facility aspect has the greatest influence on learning achievement; (2) environmental aspects have the greatest influence on CTS; (3) the three aspects of STEM learning, namely the facility aspect, teacher aspect and environmental aspect have a big influence on learning achievement and CTS; and (4) learning achievement greatly influences CTS. With this great influence, STEM learning is a learning that is very feasible to be implemented in the classroom so that learning achievement can increase and students have the CTS that are really needed in the 21st century.

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